BGP Security

Hijack and Route Leak Detection

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About me

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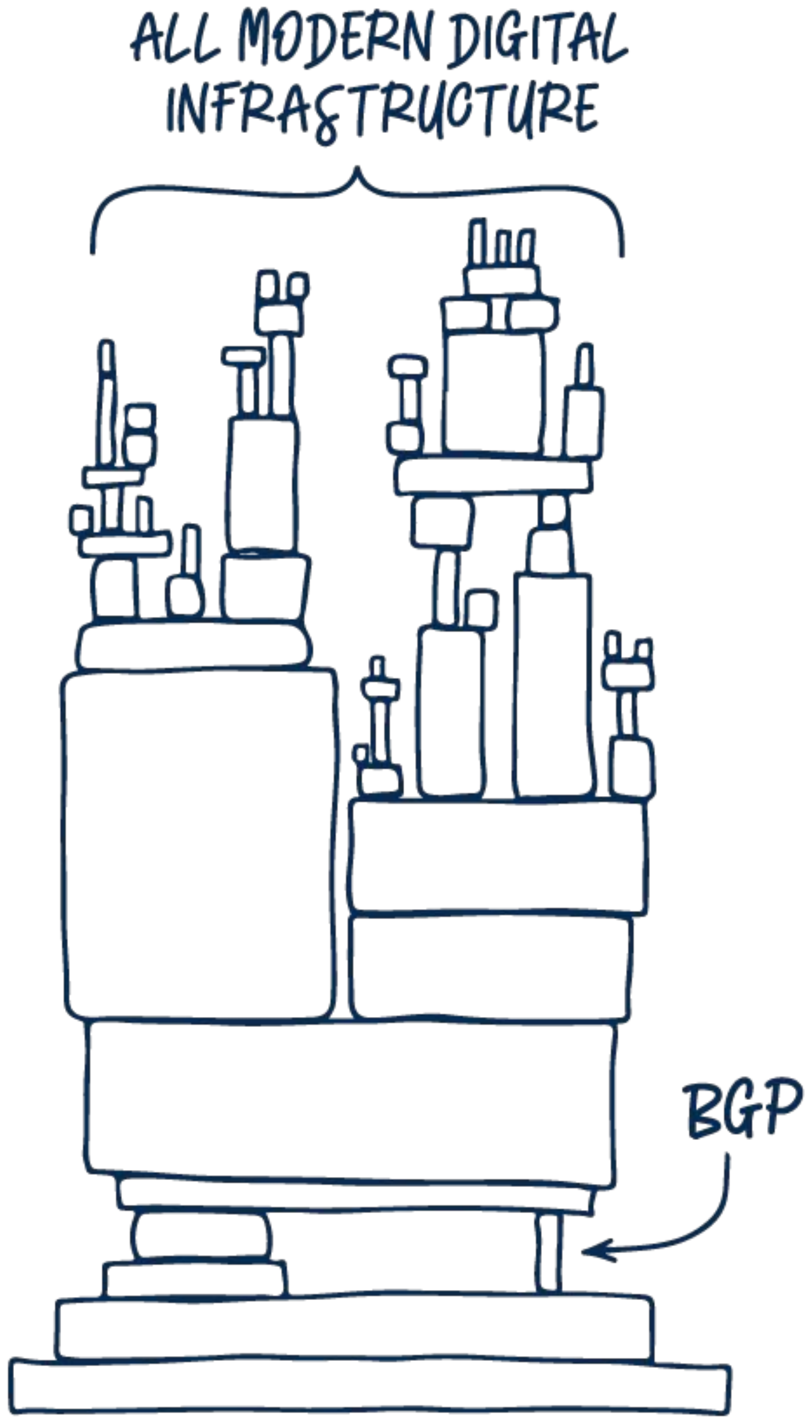
⚠ BGP hijacks, leaks & misconfigurations affect your network



- BGP events critically affect **reliability, security, and performance**
- Only the **tip of the iceberg** gets known

Types of BGP prefix hijacks

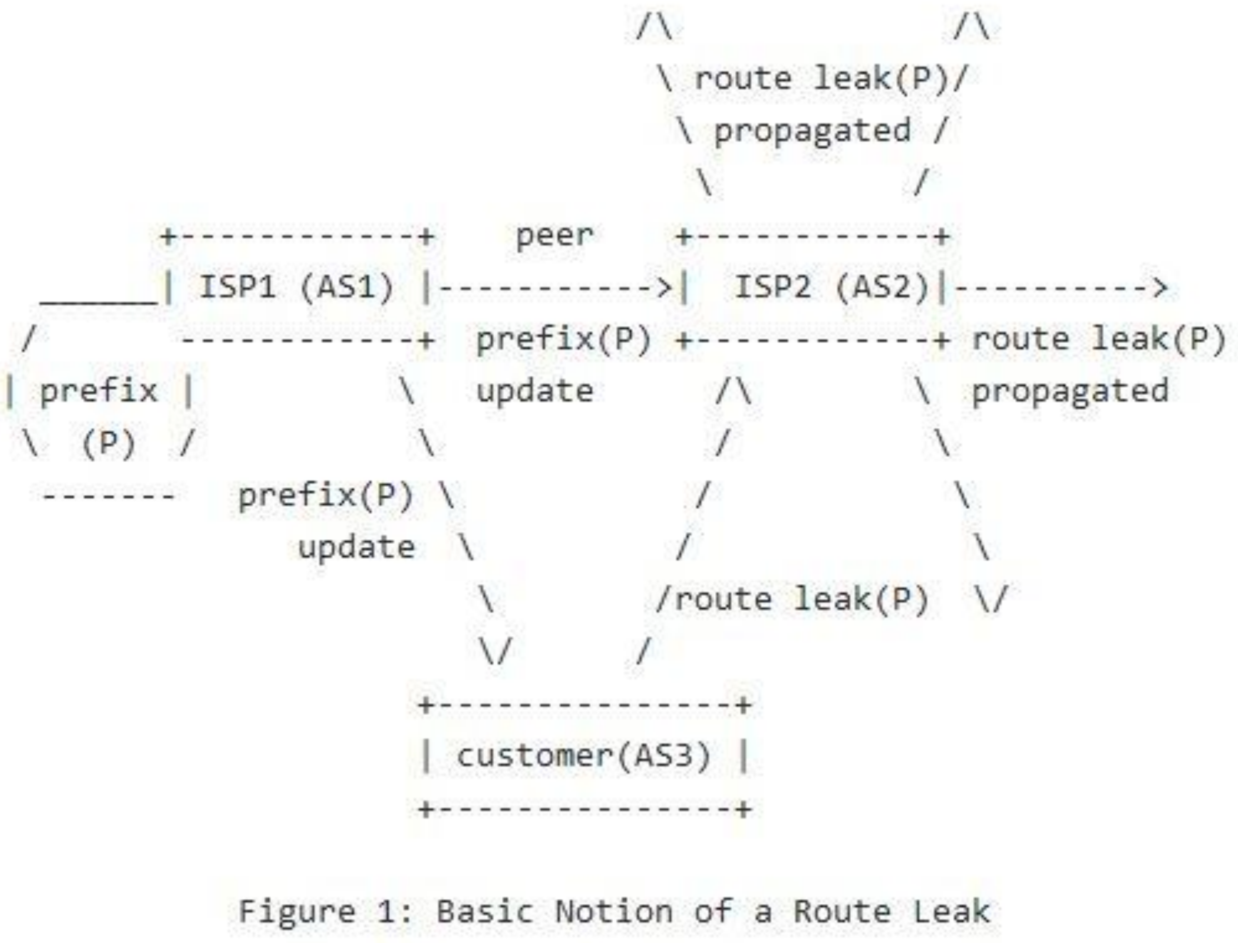
- **Classification by Announced AS-Path**
  - **Origin-AS (or Type-0):** The hijacker AS announces – as its own – a prefix that it is not authorized to originate. This is the most commonly observed hijack type.
  - **Type-N (N ≥ 1):** The hijacker AS announces an illegitimate path for a prefix it does not own. The announced path contains the ASN of the victim (first AS in the path) and hijacker, e.g., {AS50414, ASx, ASy, AS1 – 212.46.55.0/24}, while the sequence of ASes in the path is not a valid route, e.g., AS50414 is not an actual neighbor of ASx.

Types of BGP prefix hijacks

- **Classification by Affected Prefix**
  - **Exact Prefix Hijacking:** The hijacker announces a path for exactly the same prefix announced by the legitimate AS. Since shortest AS-paths are typically preferred, only a part of the Internet that is close to the hijacker (e.g., in terms of AS hops) switches to route towards the hijacker.
  - **Sub-Prefix Hijacking:** The hijacker AS announces a more specific prefix of the prefix of the legitimate AS. Since the more specific prefixes are preferred, the entire Internet routes traffic towards the hijacker to reach the announced sub-prefix.
  - **Squatting:** The hijacker AS announces a prefix owned but not (currently) announced by the owner AS.
  - For a comprehensive prefix hijack taxonomy please check the ARTEMIS paper.

Route Leaks

- **Definition:** A route leak is the propagation of routing announcement(s) beyond their intended scope.



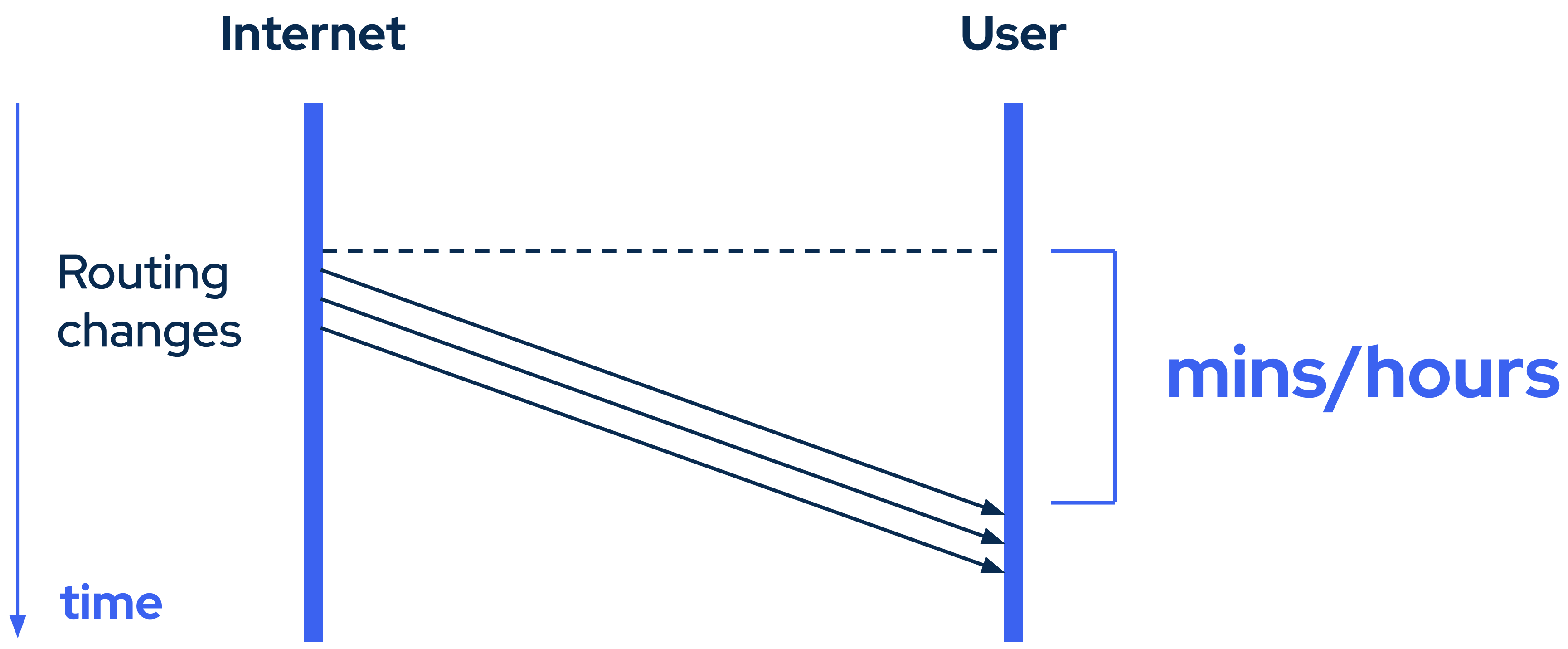
```
                                  /\               /\
                                   \ route leak(P)/
                                    \ propagated /
                                     \          /
             +------------+    peer    +------------+
       ______| ISP1 (AS1) |----------->|  ISP2 (AS2)|---------->
      /       ------------+  prefix(P) +------------+ route leak(P)
     | prefix |          \   update       /\        \  propagated
      \  (P)  /           \               /          \
       -------    prefix(P) \            /            \
                    update   \          /              \
                              \      /route leak(P)    \/
                              \/     /
                           +---------------+
                           | customer(AS3) |
                           +---------------+
```

Figure 1: Basic Notion of a Route Leak

  - ○ For different types of route leaks please check RFC 7908.

Challenges of hijack and route leak detection

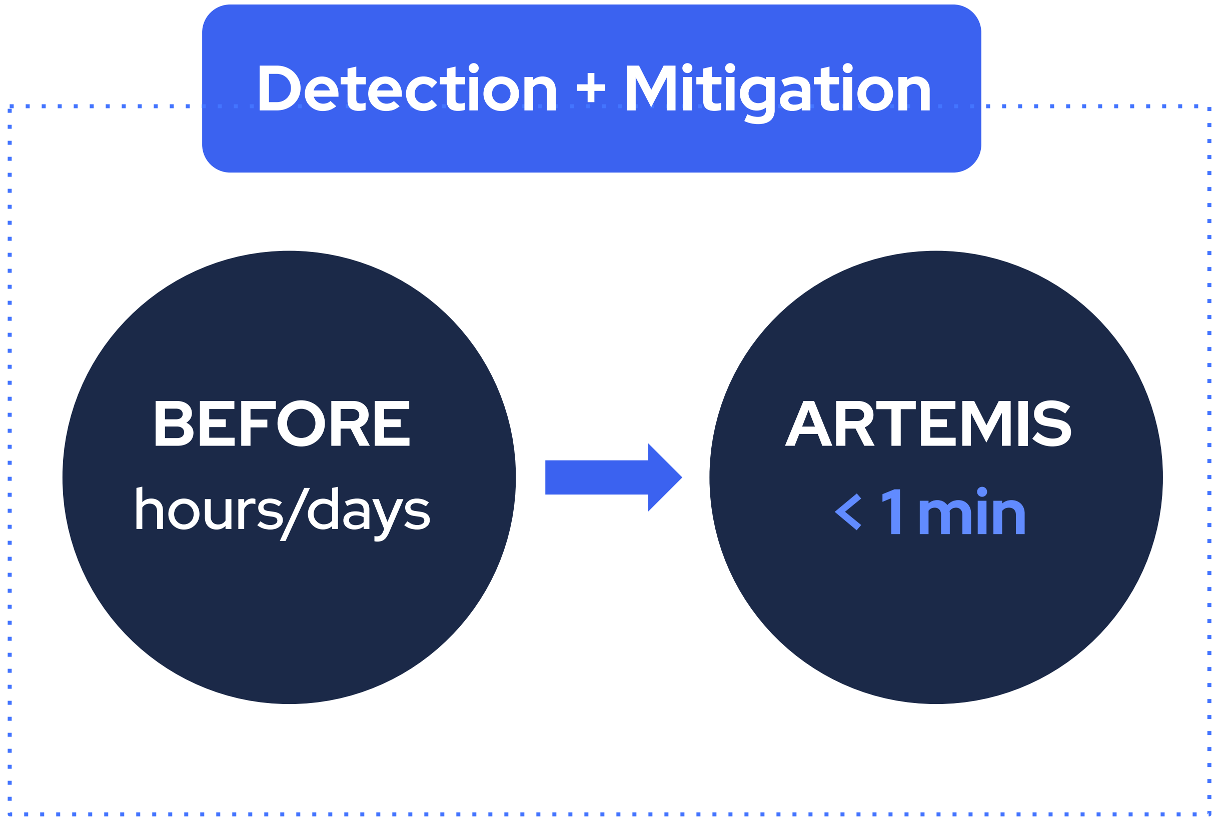
- Speed
- Accuracy
- Evasion
- Privacy and flexibility



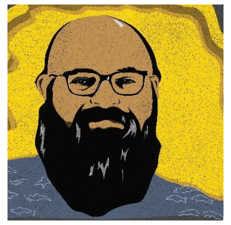
ARTEMIS

https://bgpartemis.org

- On-prem **open-source** tool we developed
- We support a community of users
- Precursor of the Code BGP Platform



- The Code BGP Platform is offered as a SaaS subscription
- Both are self-operated, leveraging the contextual knowledge of the Network Operator

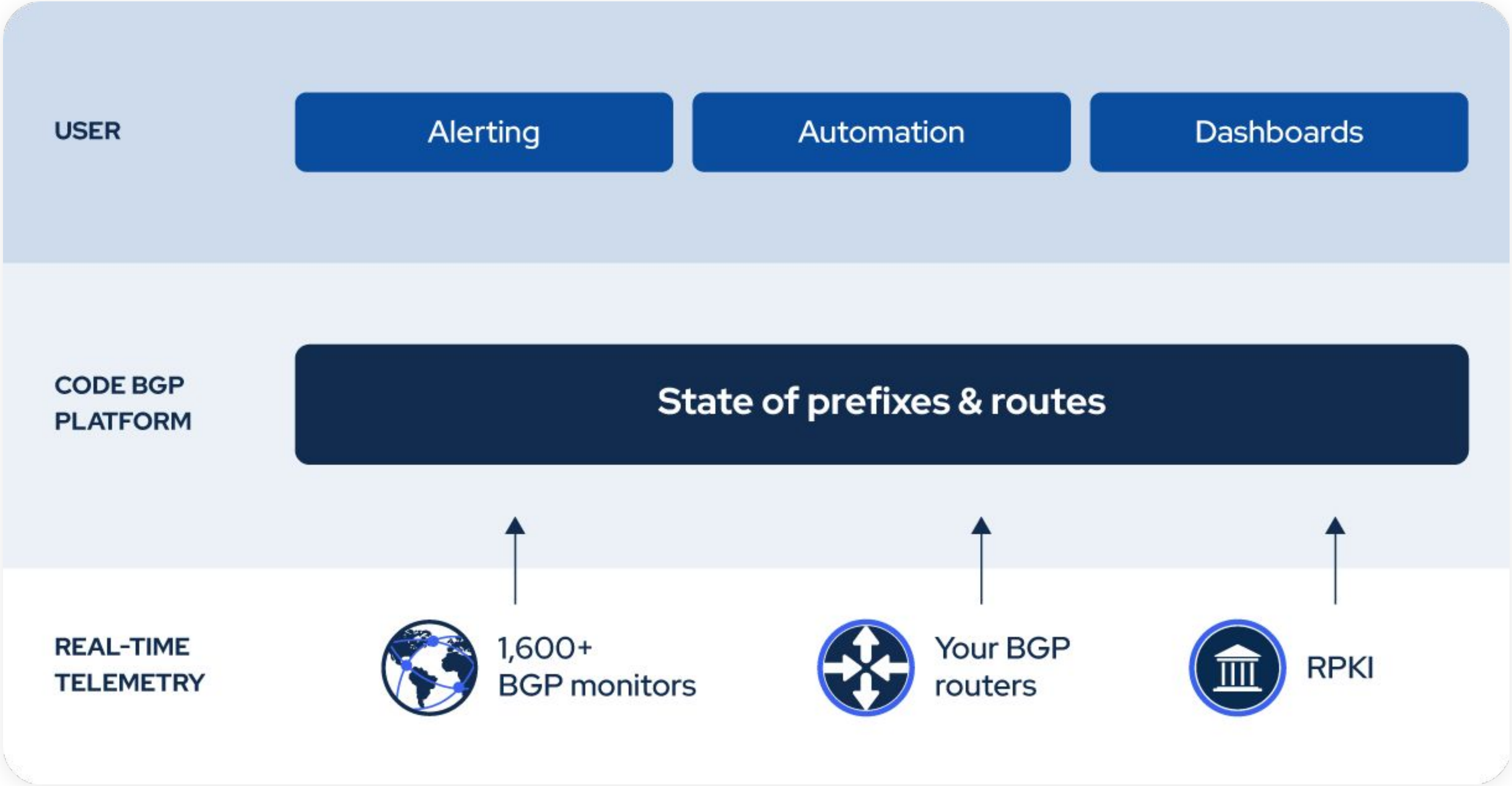


"ARTEMIS is a **fantastic** replacement for BGPmon. All around it seems like **an incredibly well-built tool** and **I use it in prod all the time**"

Chris Cummings
Network Engineer & modem.show podcast host

Code BGP Platform

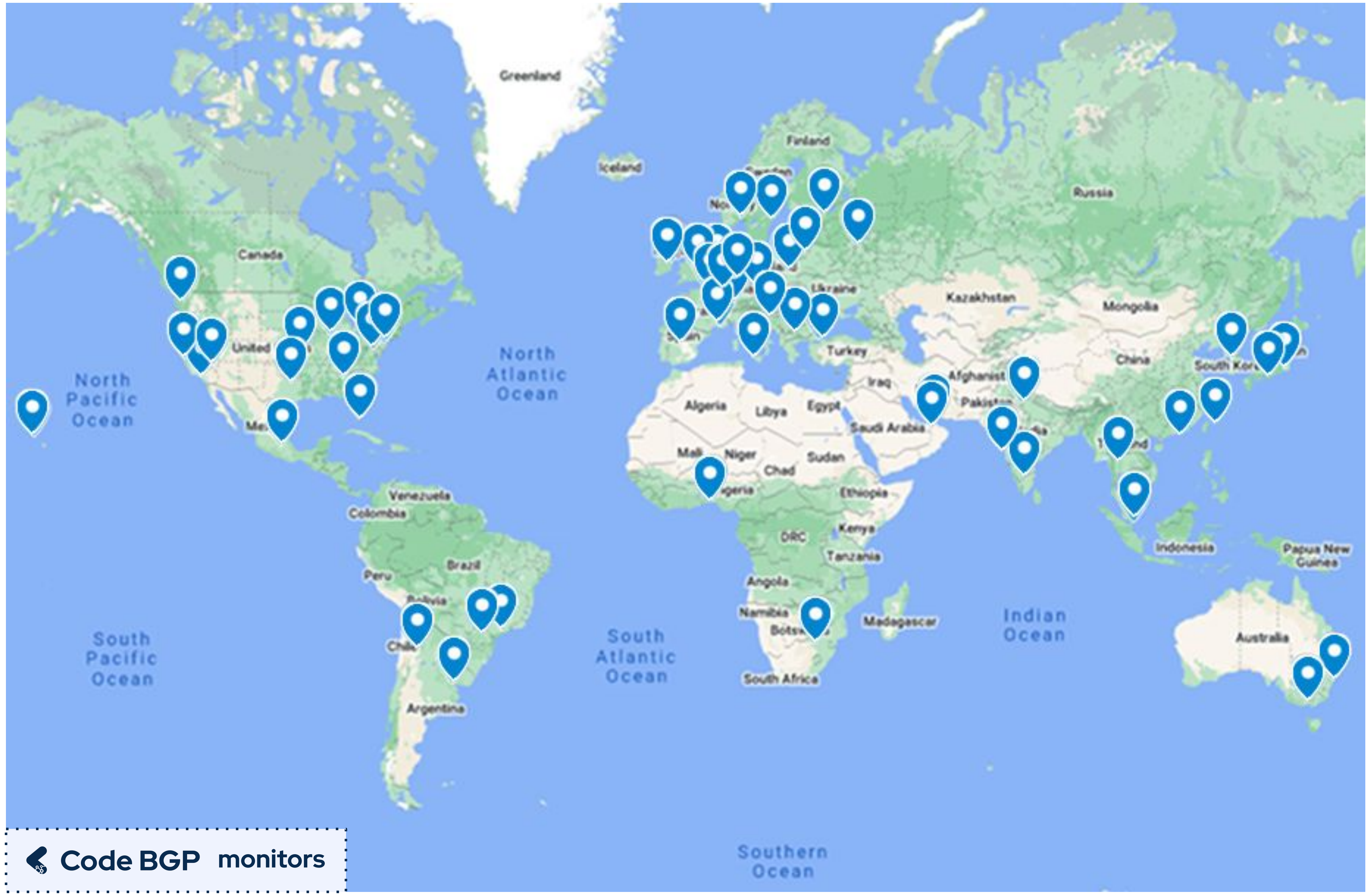
Monitor • Detect • Protect



Data service: Code BGP Monitor

BGP Monitoring Service developed by Code BGP

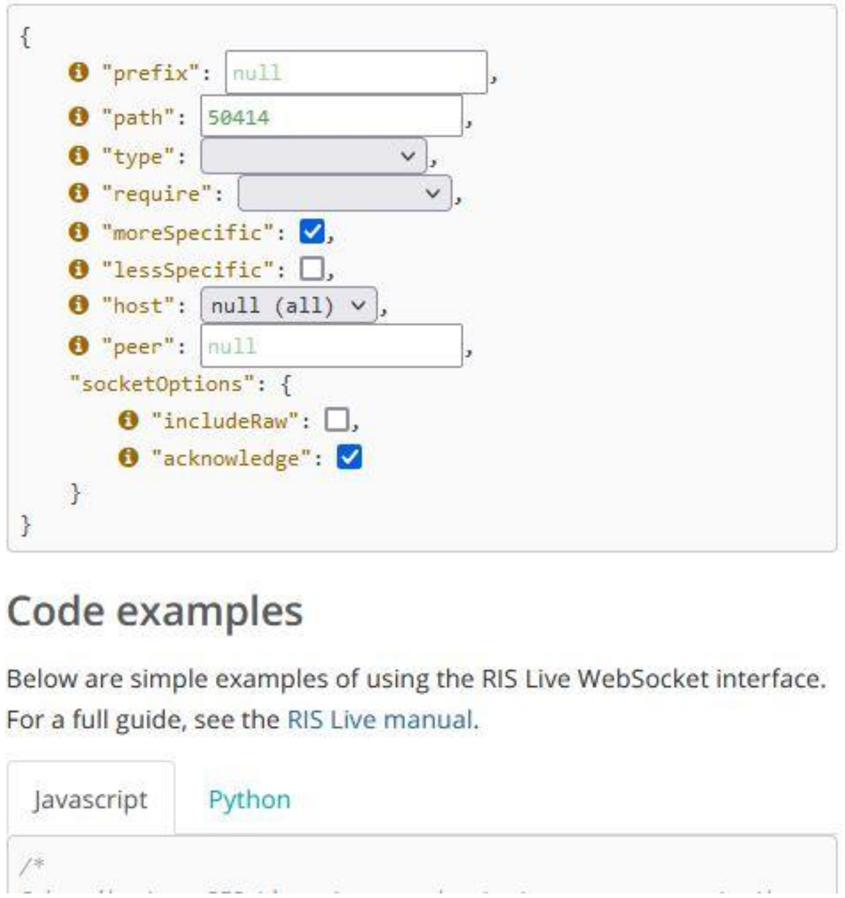
- Route Reflection (RFC 4456)
- BGP Add-Path (RFC 7911)
- 186 full feed peerings (v4 & v6)
- 20 Upstreams
- Monitors in 37 countries, 62 cities



Code BGP monitors

Data Service: RIS Live

Provides real-time JSON BGP messages via a fully filterable interactive WebSocket JSON API, and a full stream ("firehose") containing all of the messages generated by RIS. → https://ris-live.ripe.net/

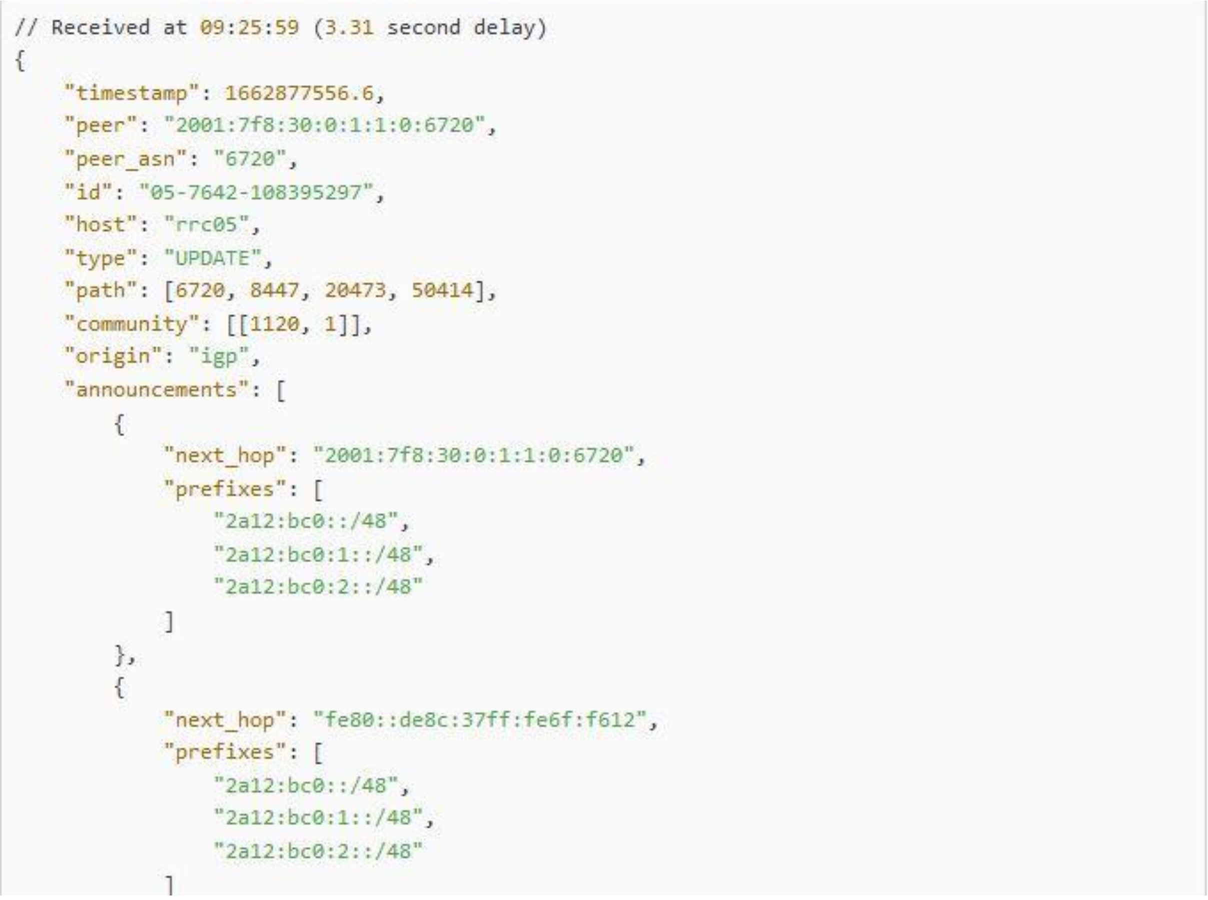


```
{
    "prefix": null,
    "path": 50414,
    "type": ,
    "require": ,
    "moreSpecific": ☑,
    "lessSpecific": □,
    "host": null (all),
    "peer": null,
    "socketOptions": {
        "includeRaw": □,
        "acknowledge": ☑
    }
}
```

Code examples

Below are simple examples of using the RIS Live WebSocket interface. For a full guide, see the RIS Live manual.

```
/*
```



```
// Received at 09:25:59 (3.31 second delay)
{
    "timestamp": 1662877556.6,
    "peer": "2001:7f8:30:0:1:1:0:6720",
    "peer_asn": "6720",
    "id": "05-7642-108395297",
    "host": "rrc05",
    "type": "UPDATE",
    "path": [6720, 8447, 20473, 50414],
    "community": [[1120, 1]],
    "origin": "igp",
    "announcements": [
        {
            "next_hop": "2001:7f8:30:0:1:1:0:6720",
            "prefixes": [
                "2a12:bc0::/48",
                "2a12:bc0:1::/48",
                "2a12:bc0:2::/48"
            ]
        },
        {
            "next_hop": "fe80::de8c:37ff:fe6f:f612",
            "prefixes": [
                "2a12:bc0::/48",
                "2a12:bc0:1::/48",
                "2a12:bc0:2::/48"
            ]
```

Total peerings (IPv4 & IPv6):
1448

BGP full feeds:

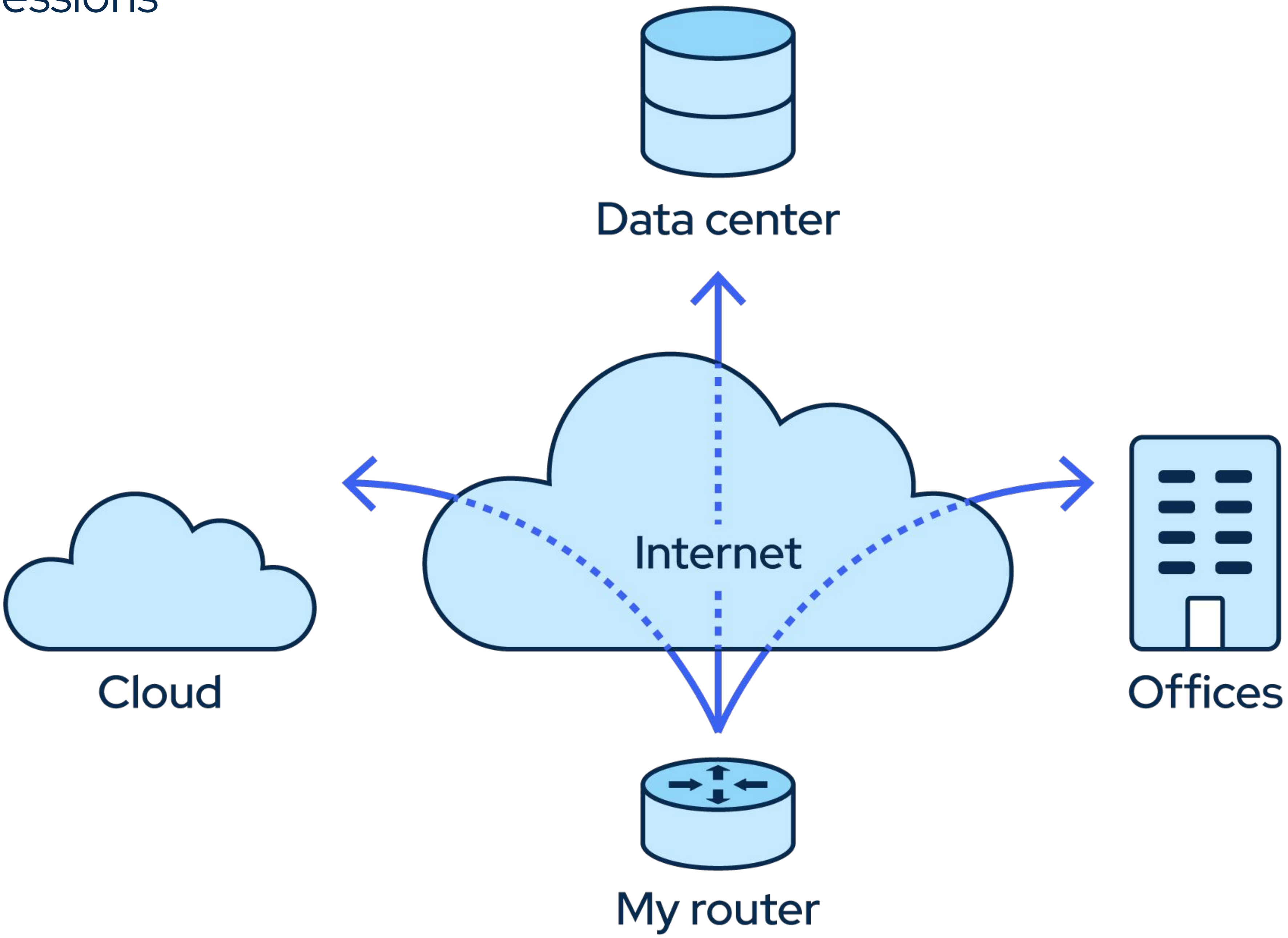
- IPv4: **366**
- IPv6: **401**

List of Route Collectors: https://ris.ripe.net/docs/10_routecollectors.html

List of Peers: https://www.ris.ripe.net/peerlist/all.shtml

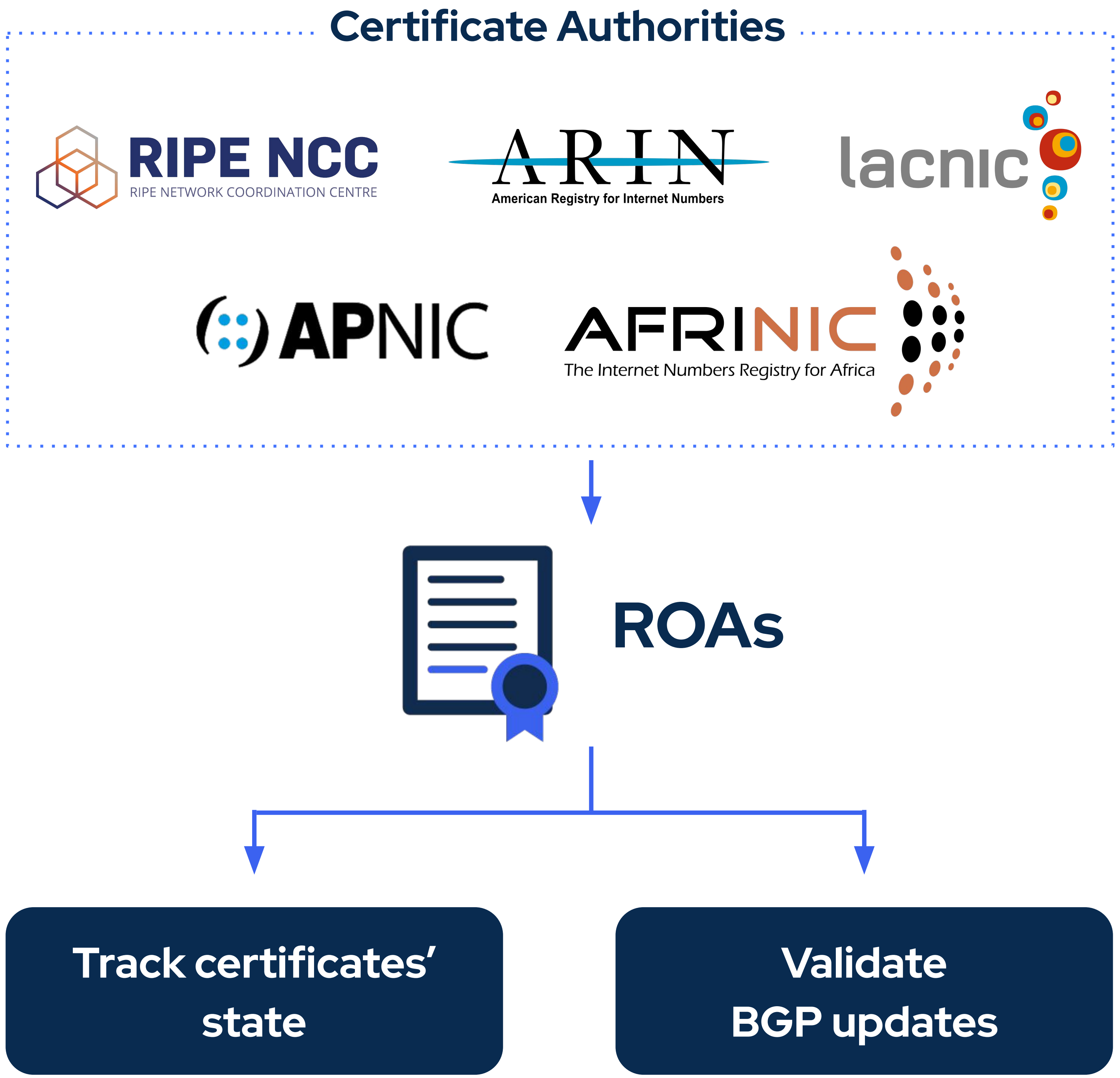
Data service: Your routers

- **Multi-hop** BGP sessions



Data Service: RPKI

- Tracking the state of **ROA certificates**
- **Validating** BGP updates and detecting **invalids**


Certificate Authorities
RIPE NCC
RIPE NETWORK COORDINATION CENTRE
ARIN
American Registry for Internet Numbers
lacnic
APNIC
AFRINIC
The Internet Numbers Registry for Africa
ROAs
Track certificates' state
Validate BGP updates

Alert Types

Supported Alert Types	Description
Exact Prefix Hijack	Illegal origin ASes that announce configured prefixes.
Sub-Prefix Hijack	Illegal origin ASes that announce subprefixes of configured prefixes.
Route Leak	Unexpected prefixes in the list of prefixes that are announced by configured ASes.
New Neighbor	New neighbors that appear to peer with configured ASes. Possible AS path manipulation.
Neighbor Leak/Hijack	New neighbors that not only appear to peer with configured ASes, but also propagate their prefixes.
Squatting	Illegal origin ASes announcing prefixes that are not currently announced by configured ASes.
Presence in AS Path	Presence of ASes in paths towards configured prefixes.
Invalid AS Path Pattern	Violation of valid pattern by AS paths towards configured prefixes.
Prefix Visibility Loss	Visibility of prefix falls below a configured data source count threshold.
Peering Visibility Loss	Visibility of peering falls below a configured data source count threshold.

Supported Alert Types	Description
RPKI-Invalid Detection	RPKI-Invalid announcements of configured prefixes by other ASes.
RPKI-Invalid Announcement	RPKI-Invalid announcements by configured ASes.
RPKI-Invalid Propagation	RPKI-Invalid routes propagated by configured ASes.
RPKI-NotFound Propagation	RPKI-NotFound routes propagated by configured ASes.
Bogon (Exact-)Prefix	Announcements of bogon prefixes by configured ASes.
Bogon (Sub-)Prefix	Announcements of bogon subprefixes by configured ASes.
Bogon AS	In-path presence of bogon ASes, in routes towards configured prefixes.
AS Path Comparison	Discrepancies in AS paths towards the same prefix, comparing between different Data Services, up to a terminating (end) AS.
Prefix Comparison	Discrepancies in prefixes announced by configured ASes, comparing between different Data Services.
Custom	User-defined

GraphQL basics

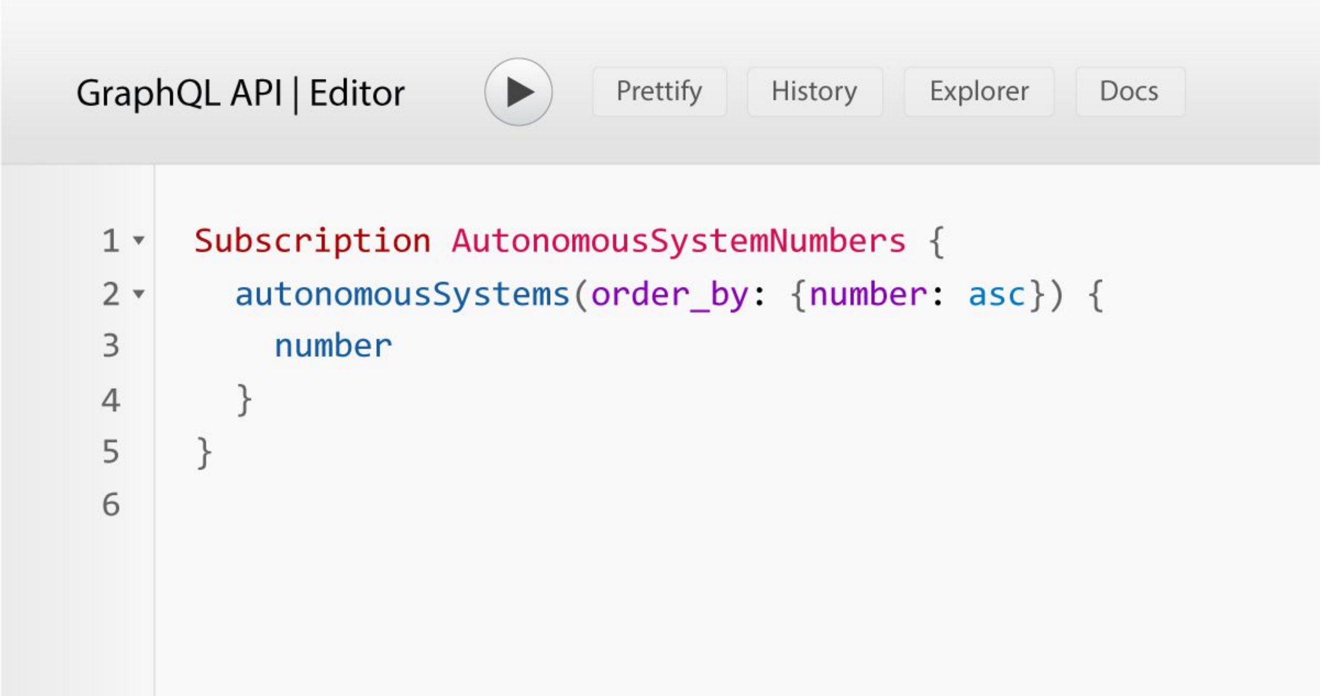
- **What it is**
  - Query language for APIs
  - Runtime for fulfilling queries with existing data

- **Features**
  - Ask exactly the data you need
  - Get many resources in single request
  - Single endpoint + type system: organized in terms of types and fields, not endpoints
  - No-version API evolution
  - Integration with own data + code
  - Supports subscriptions

GraphQL subscriptions

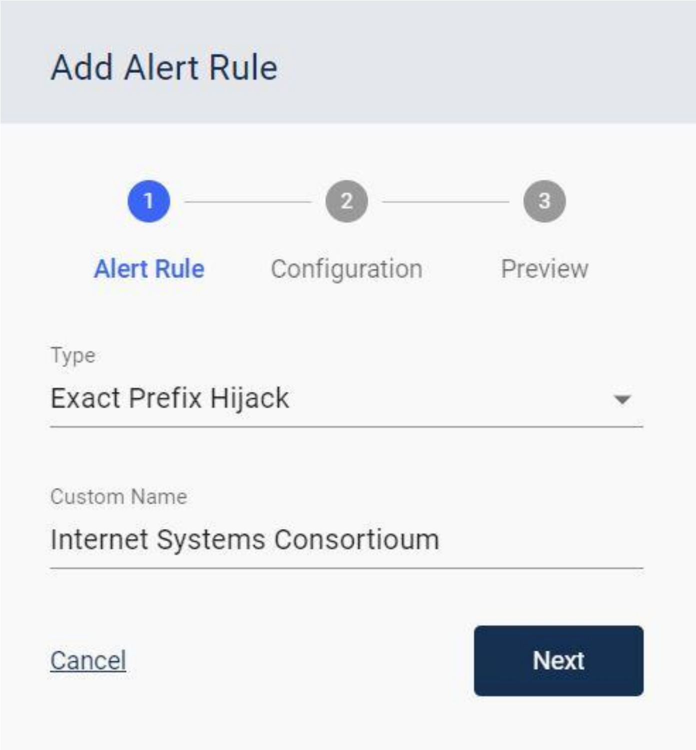
- Subscriptions are a **GraphQL feature** that allows a server to send data to its clients when a specific event happens. They are implemented with WebSockets, and the server maintains a steady connection to its subscribed client. This also breaks the “Request-Response-Cycle” that were used for all previous interactions with the API.

- Instead, the client initially opens up a **long-lived connection** to the server by sending a subscription query that specifies which event it is interested in. Every time this particular event happens, the server uses the connection to push the event data to the subscribed client(s).



```
Subscription AutonomousSystemNumbers {
  autonomousSystems(order_by: {number: asc}) {
    number
  }
}
```

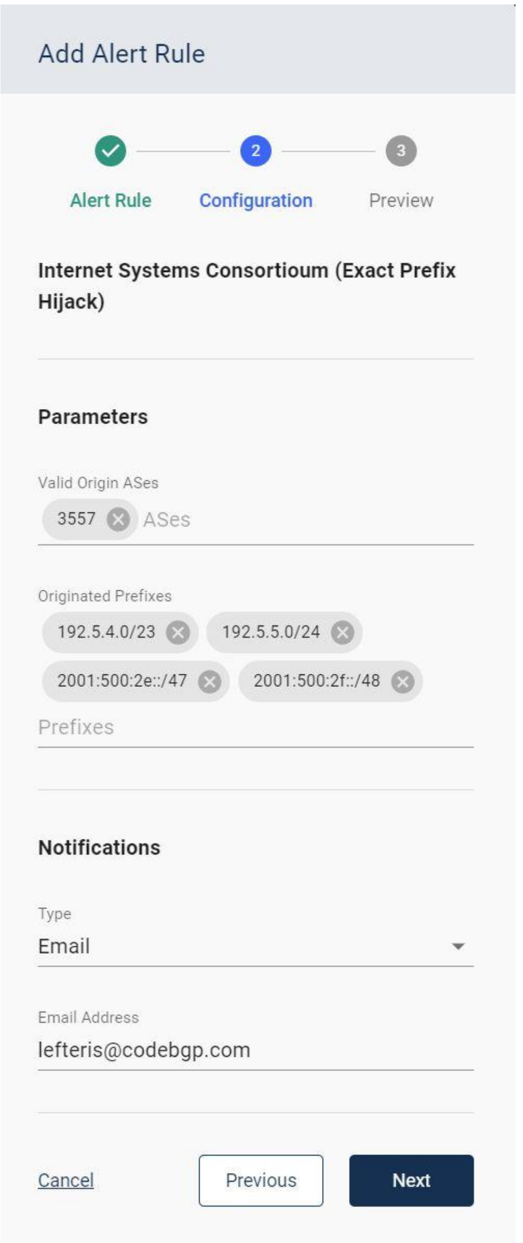
Insert Alert Rules using the UI



Add Alert Rule

Type: Exact Prefix Hijack

Custom Name: Internet Systems Consortioum



Add Alert Rule

Internet Systems Consortioum (Exact Prefix Hijack)

Parameters

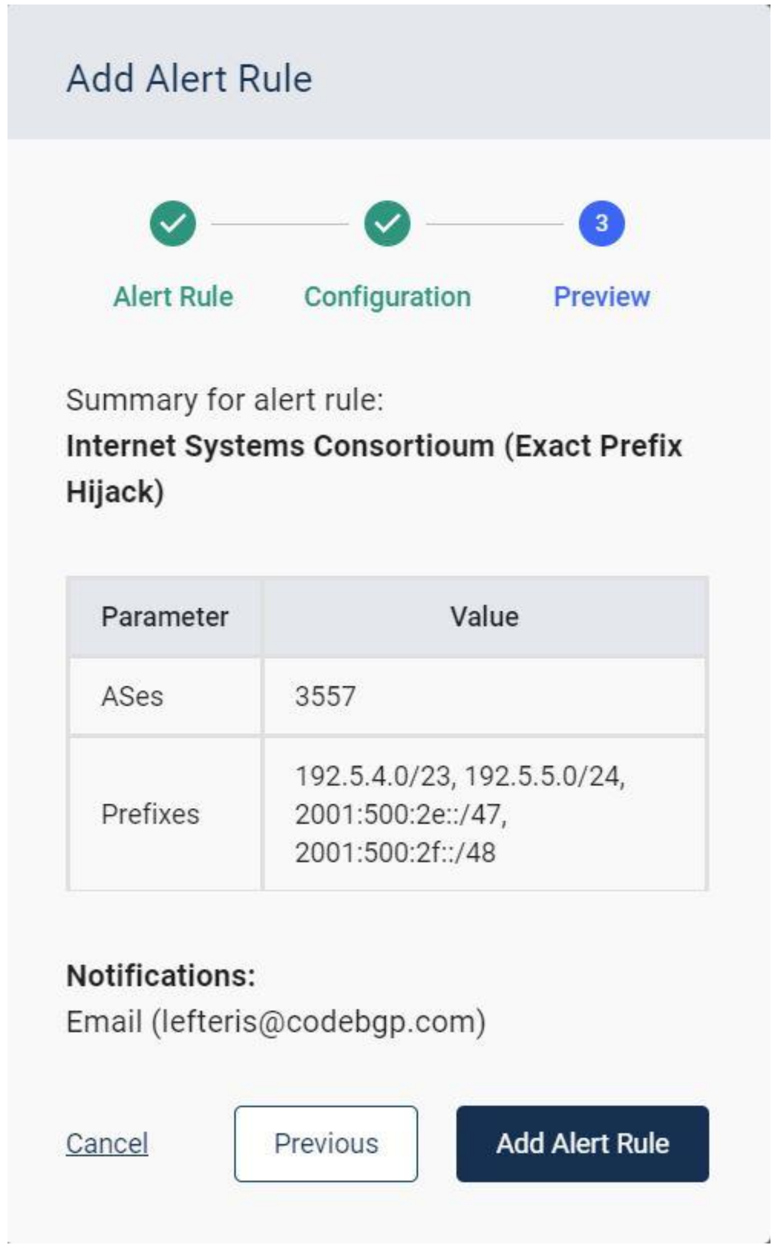
Valid Origin ASes: 3557 ⊗ ASes

Originated Prefixes: 192.5.4.0/23 ⊗ 192.5.5.0/24 ⊗ 2001:500:2e::/47 ⊗ 2001:500:2f::/48 ⊗ Prefixes

Notifications

Type: Email

Email Address: lefteris@codebgp.com

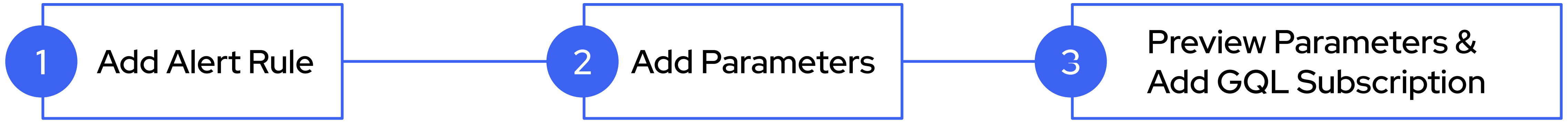


Add Alert Rule

Summary for alert rule:
Internet Systems Consortioum (Exact Prefix Hijack)

Parameter	Value
ASes	3557
Prefixes	192.5.4.0/23, 192.5.5.0/24, 2001:500:2e::/47, 2001:500:2f::/48

Notifications:
Email (lefteris@codebgp.com)



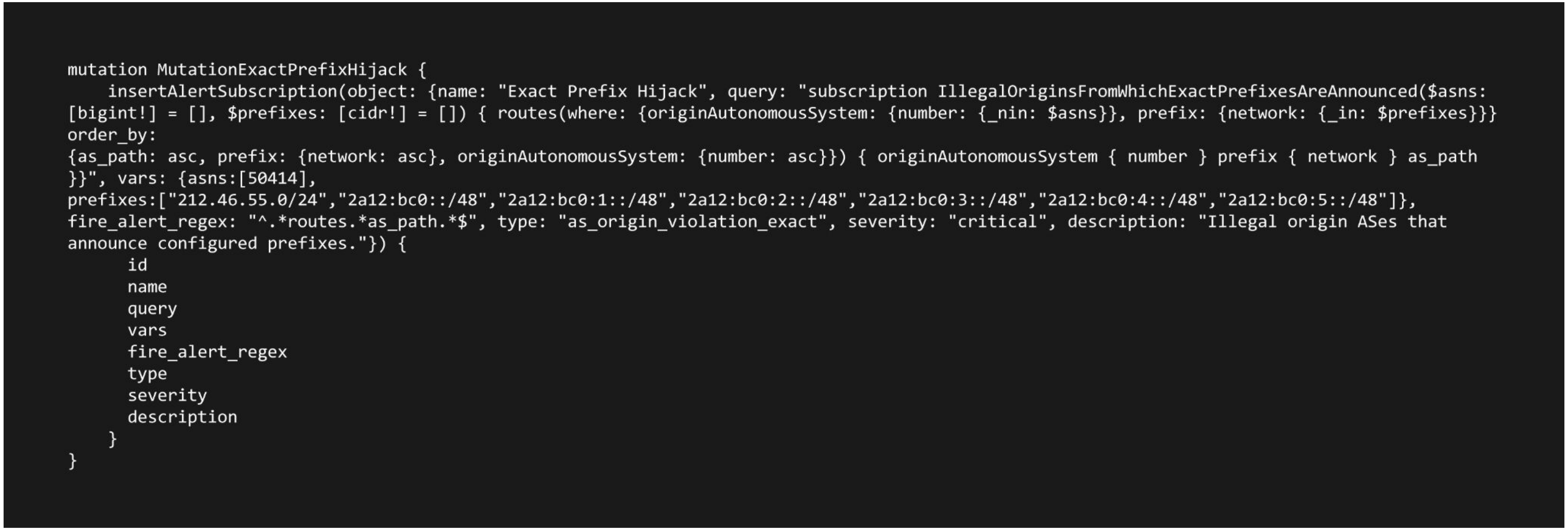
1 Add Alert Rule

2 Add Parameters

3 Preview Parameters & Add GQL Subscription

How we use GraphQL Subscriptions for Alert Rules

- **Example** of a subscription query (which is entered to the system as a mutation) to detect exact prefix hijacks for prefixes belonging to Code BGP (AS 50414).



```
mutation MutationExactPrefixHijack {
    insertAlertSubscription(object: {name: "Exact Prefix Hijack", query: "subscription IllegalOriginsFromWhichExactPrefixesAreAnnounced($asns:
[bigint!] = [], $prefixes: [cidr!] = []) { routes(where: {originAutonomousSystem: {number: {_nin: $asns}}, prefix: {network: {_in: $prefixes}}}
order_by:
{as_path: asc, prefix: {network: asc}, originAutonomousSystem: {number: asc}}) { originAutonomousSystem { number } prefix { network } as_path
}}", vars: {asns:[50414],
prefixes:["212.46.55.0/24","2a12:bc0::/48","2a12:bc0:1::/48","2a12:bc0:2::/48","2a12:bc0:3::/48","2a12:bc0:4::/48","2a12:bc0:5::/48"]},
fire_alert_regex: "^.*routes.*as_path.*$", type: "as_origin_violation_exact", severity: "critical", description: "Illegal origin ASes that
announce configured prefixes."}) {
        id
        name
        query
        vars
        fire_alert_regex
        type
        severity
        description
    }
}
```

Root DNS Servers

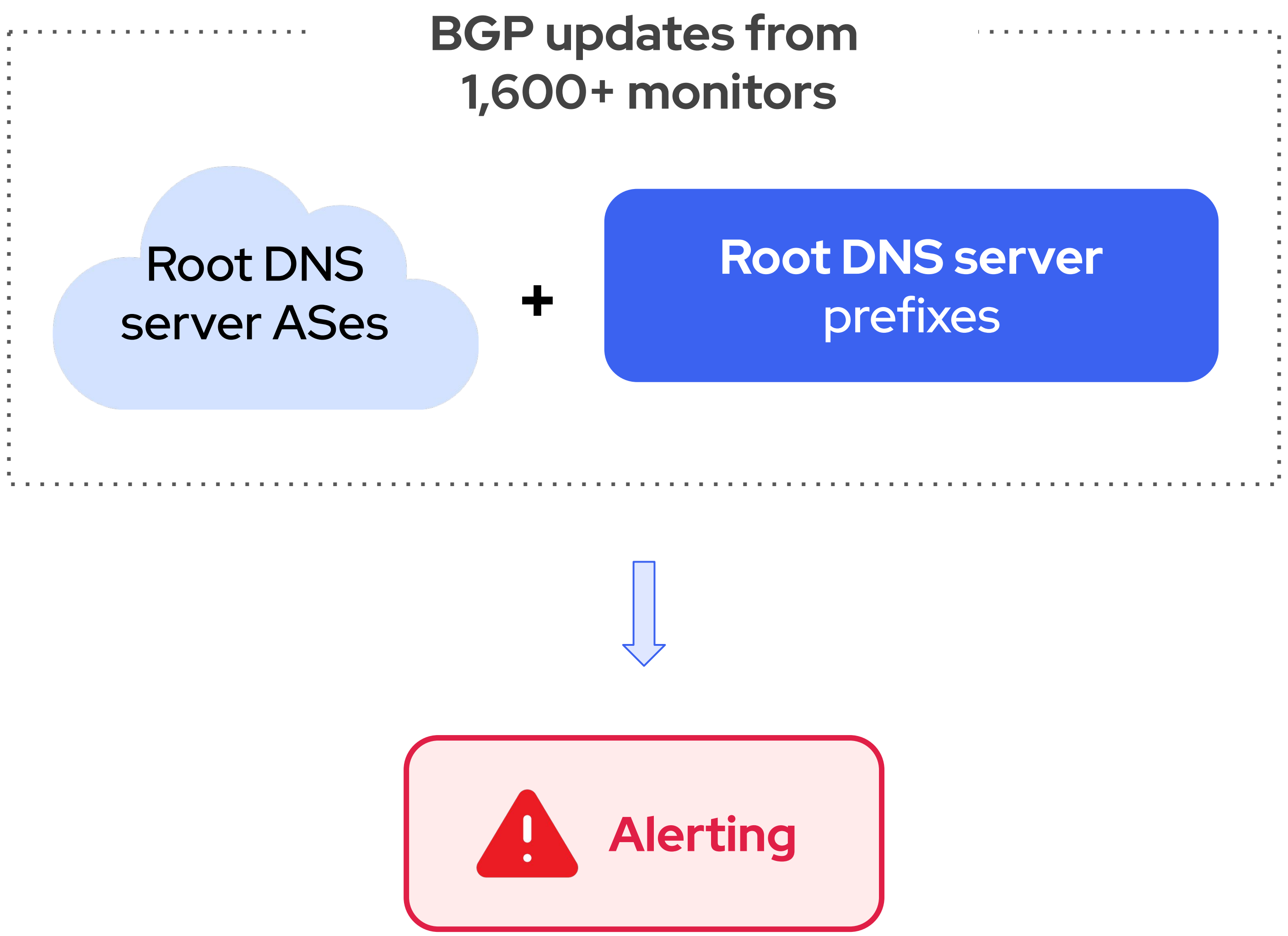
- The authoritative name servers that serve the DNS root zone

Name	IPv4	IPv6	Operator
A-Root	198.41.0.4	2001:503:ba3e::2:30	Verisign, Inc.
B-Root	199.9.14.201	2001:500:200::b	USC, Information Sciences Institute
C-Root	192.33.4.12	2001:500:2::c	Cogent Communications
D-Root	199.7.91.13	2001:500:2d::d	University of Maryland
E-Root	192.203.230.10	2001:500:a8::e	NASA (Ames Research Center)
F-Root	192.5.5.241	2001:500:2f::f	Internet Systems Consortium, Inc.
G-Root	192.112.36.4	2001:500:12::d0d	US Department of Defense (NIC)
H-Root	198.97.190.53	2001:500:1::53	US Army (Research Lab)
I-Root	192.36.148.17	2001:7fe::53	Netnod
J-Root	192.58.128.30	2001:503:c27::2:30	Verisign, Inc.
K-Root	193.0.14.129	2001:7fd::1	RIPE NCC
I-Root	199.7.83.42	2001:500:9f::42	ICANN
M-Root	202.12.27.33	2001:dc3::35	WIDE Project

Why Monitoring Root DNS Server Prefixes

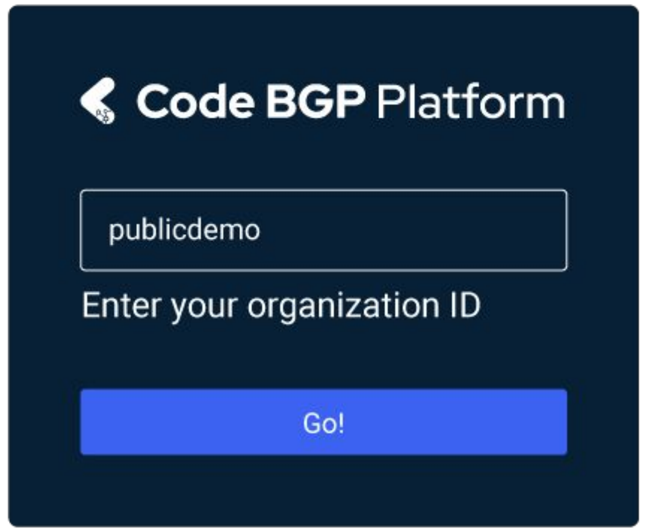
- Critical Internet infrastructure, worth protecting
- These prefixes are heavily anycasted
    - BGP anomalies (e.g. exact prefix hijacks) will go largely unnoticed, due to their limited impact on the data plane

We provide access for free to a Code BGP Platform instance which monitors the root DNS prefixes



How to get access to the Route DNS monitoring instance

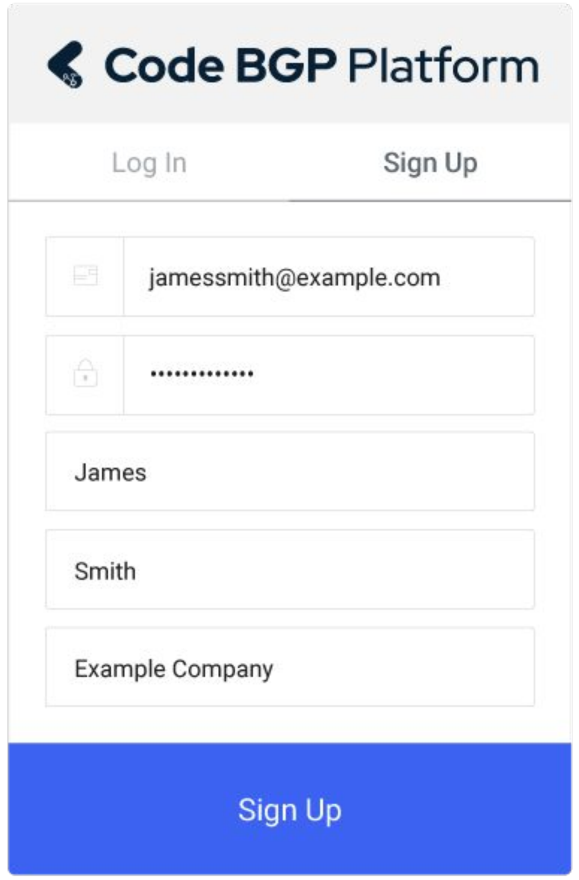
- Go to https://cloud.codebgp.com/ and in the Organisation ID type “publicdemo”
- Sign up
- Docs: https://docs.codebgp.com/



Code BGP Platform

publicdemo

Enter your organization ID



Code BGP Platform

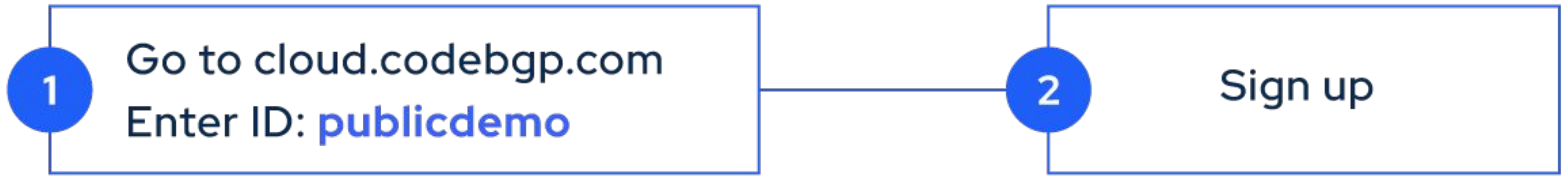
jamessmith@example.com

••••••••••••••

James

Smith

Example Company

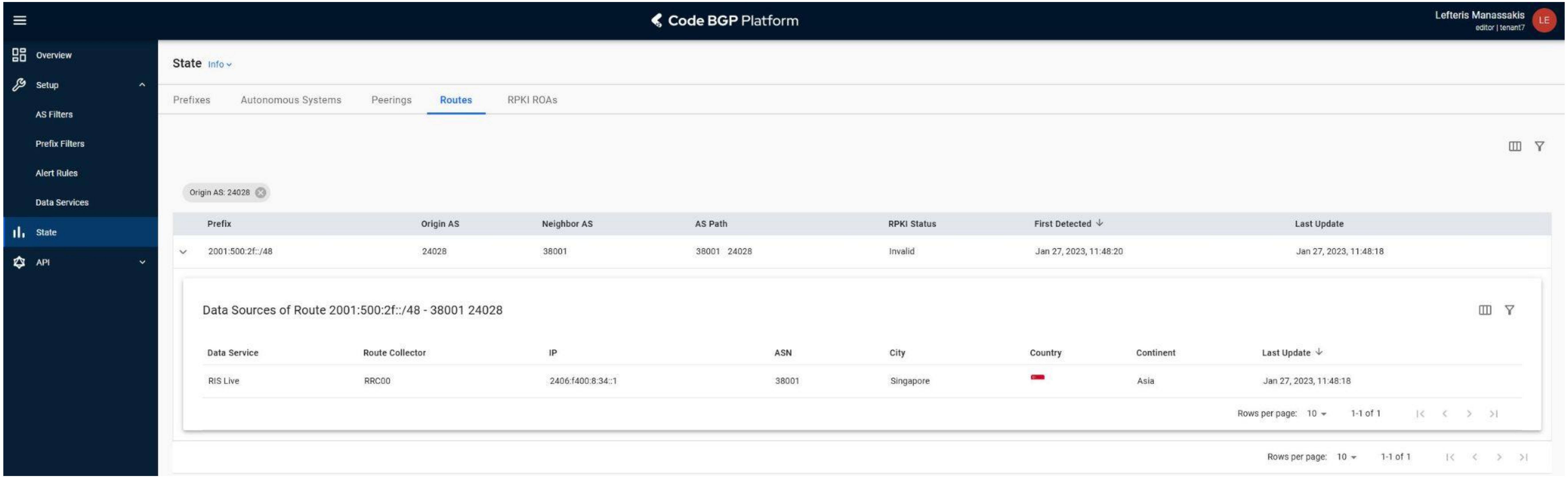


1 Go to cloud.codebgp.com
Enter ID: **publicdemo**

2 Sign up

Exact Prefix Hijack detected for root DNS prefix - Jan 27

- AS 24028 announced prefix 2001:500:2f::/48 which belongs to ISC, and serves as the IPv6 prefix of the “F-Root” domain server (AS 3557)
- Seen only by one source, which happens to be a neighbor of the offending network. The limited propagation is possibly due to RPKI ROV



Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	First Detected ↓	Last Update
2001:500:2f::/48	24028	38001	38001 24028	Invalid	Jan 27, 2023, 11:48:20	Jan 27, 2023, 11:48:18

Data Sources of Route 2001:500:2f::/48 - 38001 24028

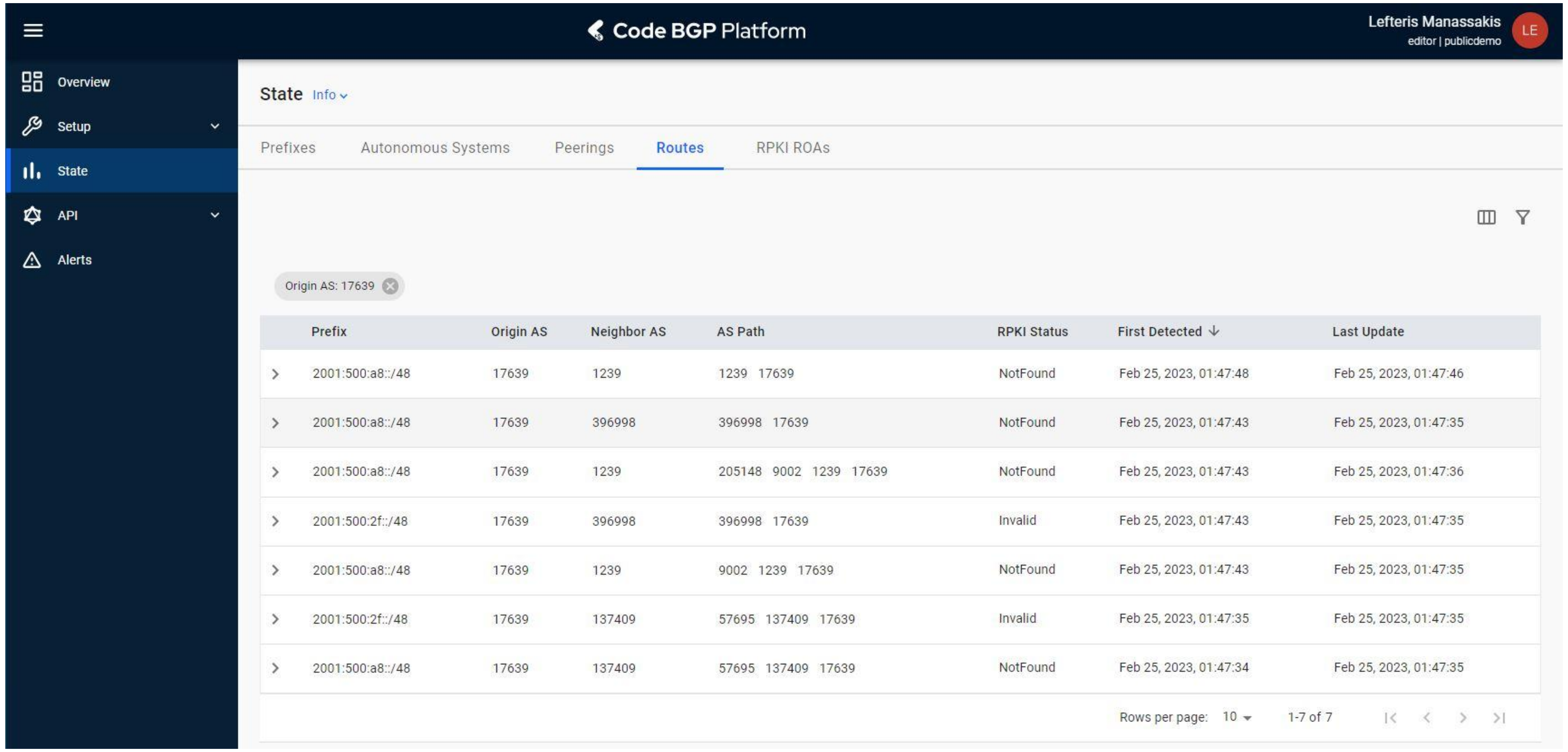
Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
RIS Live	RRC00	2406:f400:8:34::1	38001	Singapore	🇸🇬	Asia	Jan 27, 2023, 11:48:18

Rows per page: 10 1-1 of 1

Rows per page: 10 1-1 of 1

Exact Prefix Hijacks detected for root DNS prefixes - Feb. 25

- AS 7639 announced prefix 2001:500:a8::/48 which belongs to NASA and is the IPv6 prefix of the "E-Root" domain server (AS 21556)
- At the exact same time, the same AS 7639 announced prefix 2001:500:2f::/48 which belongs to F-Root (ISC AS 3557)



State Info

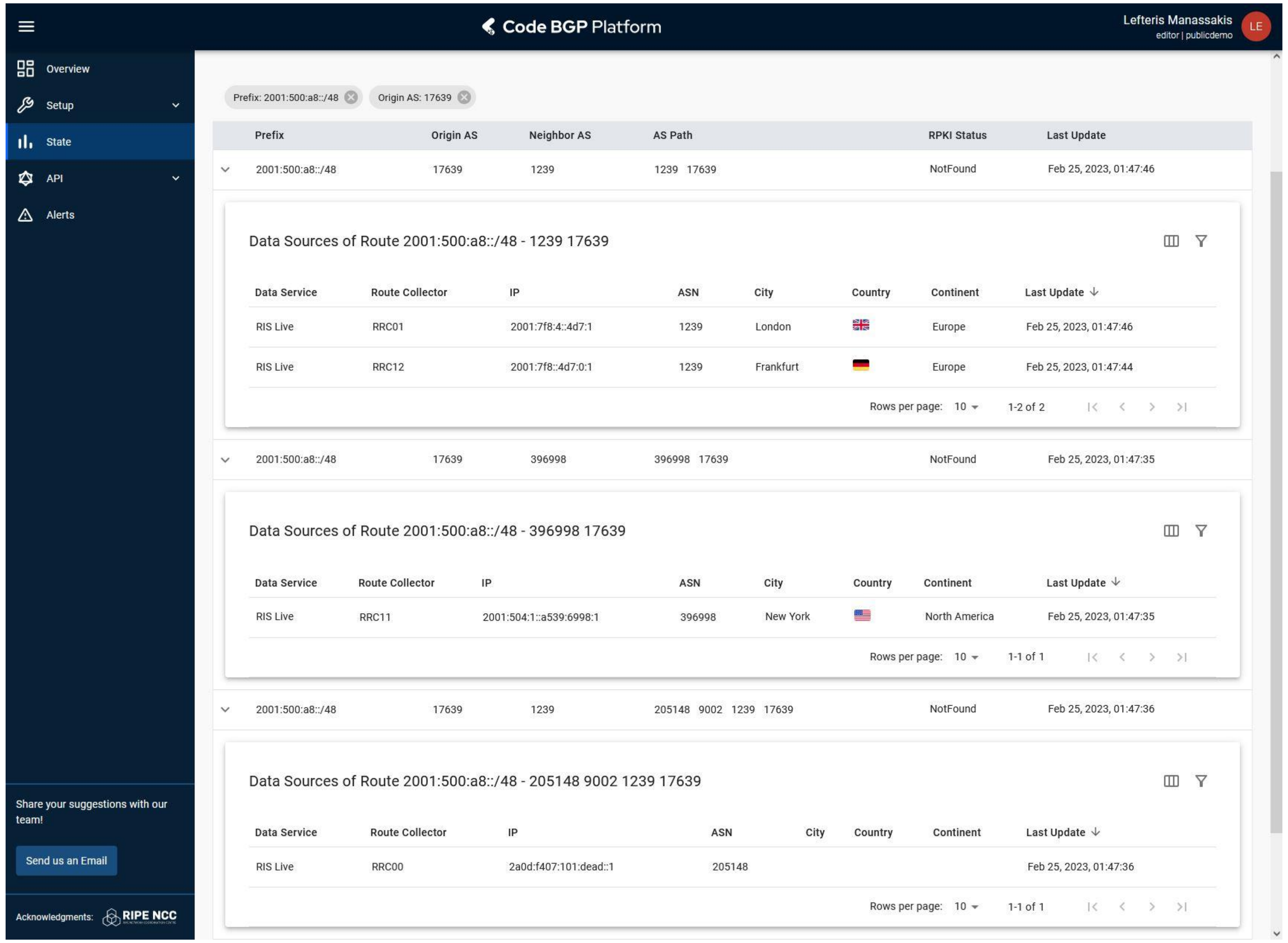
Origin AS: 17639

Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	First Detected	Last Update
2001:500:a8::/48	17639	1239	1239 17639	NotFound	Feb 25, 2023, 01:47:48	Feb 25, 2023, 01:47:46
2001:500:a8::/48	17639	396998	396998 17639	NotFound	Feb 25, 2023, 01:47:43	Feb 25, 2023, 01:47:35
2001:500:a8::/48	17639	1239	205148 9002 1239 17639	NotFound	Feb 25, 2023, 01:47:43	Feb 25, 2023, 01:47:36
2001:500:2f::/48	17639	396998	396998 17639	Invalid	Feb 25, 2023, 01:47:43	Feb 25, 2023, 01:47:35
2001:500:a8::/48	17639	1239	9002 1239 17639	NotFound	Feb 25, 2023, 01:47:43	Feb 25, 2023, 01:47:35
2001:500:2f::/48	17639	137409	57695 137409 17639	Invalid	Feb 25, 2023, 01:47:35	Feb 25, 2023, 01:47:35
2001:500:a8::/48	17639	137409	57695 137409 17639	NotFound	Feb 25, 2023, 01:47:34	Feb 25, 2023, 01:47:35

Rows per page: 10 1-7 of 7

Exact Prefix Hijacks detected for root DNS prefixes - Feb. 25

- The “E-Root” 2001:500:a8::/48 prefix is not covered by a RPKI ROA. The event lasted 2 days



Prefix: 2001:500:a8::/48 ⊗ Origin AS: 17639 ⊗

Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:a8::/48	17639	1239	1239 17639	NotFound	Feb 25, 2023, 01:47:46

Data Sources of Route 2001:500:a8::/48 - 1239 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
RIS Live	RRC01	2001:7f8:4::4d7:1	1239	London	🇬🇧	Europe	Feb 25, 2023, 01:47:46
RIS Live	RRC12	2001:7f8::4d7:0:1	1239	Frankfurt	🇩🇪	Europe	Feb 25, 2023, 01:47:44

Rows per page: 10 1-2 of 2

Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:a8::/48	17639	396998	396998 17639	NotFound	Feb 25, 2023, 01:47:35

Data Sources of Route 2001:500:a8::/48 - 396998 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
RIS Live	RRC11	2001:504:1::a539:6998:1	396998	New York	🇺🇸	North America	Feb 25, 2023, 01:47:35

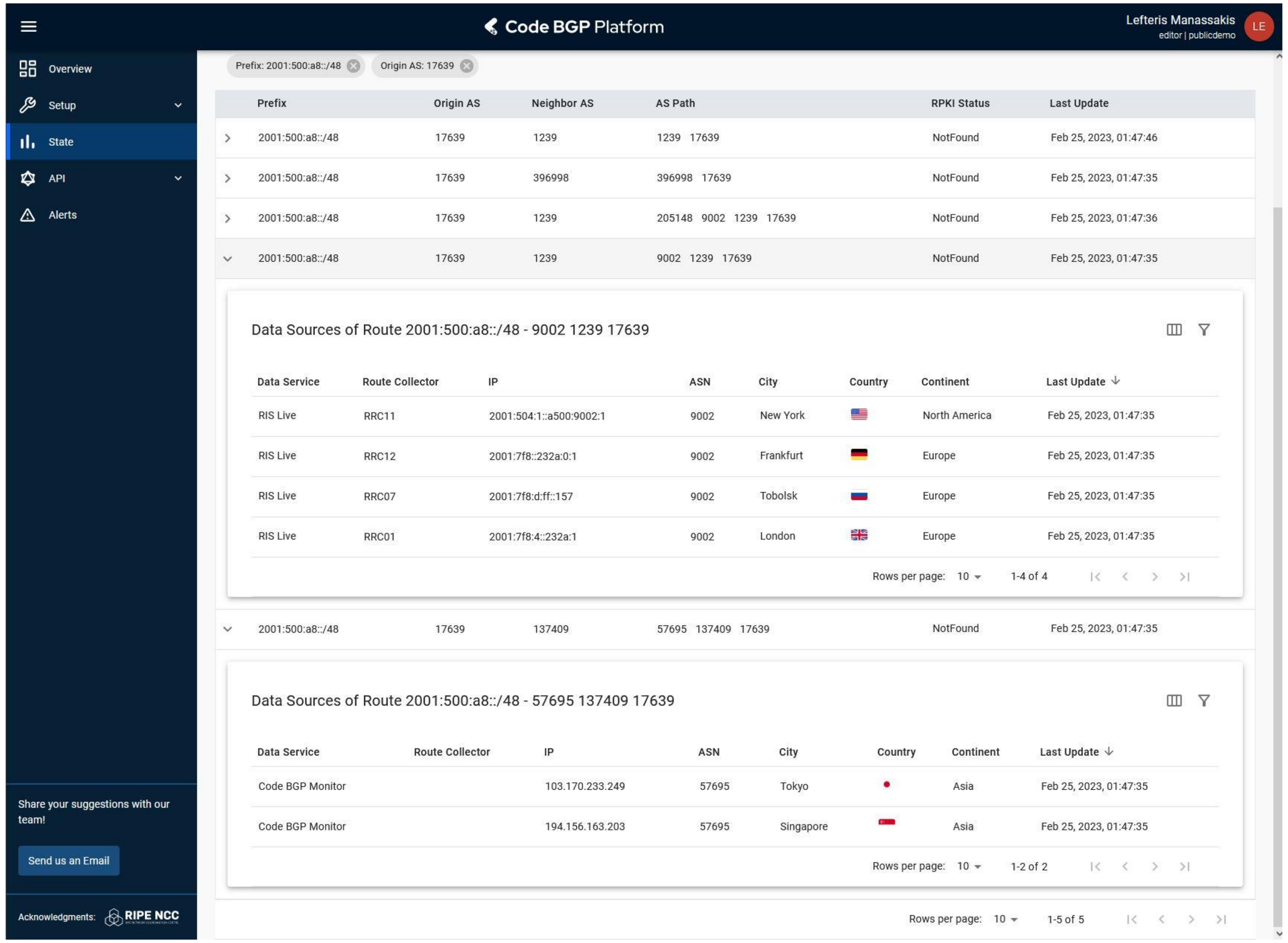
Rows per page: 10 1-1 of 1

Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:a8::/48	17639	1239	205148 9002 1239 17639	NotFound	Feb 25, 2023, 01:47:36

Data Sources of Route 2001:500:a8::/48 - 205148 9002 1239 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
RIS Live	RRC00	2a0d:f407:101:dead::1	205148				Feb 25, 2023, 01:47:36

Rows per page: 10 1-1 of 1



Prefix: 2001:500:a8::/48 ⊗ Origin AS: 17639 ⊗

Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:a8::/48	17639	1239	1239 17639	NotFound	Feb 25, 2023, 01:47:46
2001:500:a8::/48	17639	396998	396998 17639	NotFound	Feb 25, 2023, 01:47:35
2001:500:a8::/48	17639	1239	205148 9002 1239 17639	NotFound	Feb 25, 2023, 01:47:36
2001:500:a8::/48	17639	1239	9002 1239 17639	NotFound	Feb 25, 2023, 01:47:35

Data Sources of Route 2001:500:a8::/48 - 9002 1239 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
RIS Live	RRC11	2001:504:1::a500:9002:1	9002	New York	🇺🇸	North America	Feb 25, 2023, 01:47:35
RIS Live	RRC12	2001:7f8::232a:0:1	9002	Frankfurt	🇩🇪	Europe	Feb 25, 2023, 01:47:35
RIS Live	RRC07	2001:7f8:d:ff::157	9002	Tobolsk	🇷🇺	Europe	Feb 25, 2023, 01:47:35
RIS Live	RRC01	2001:7f8:4::232a:1	9002	London	🇬🇧	Europe	Feb 25, 2023, 01:47:35

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Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:a8::/48	17639	137409	57695 137409 17639	NotFound	Feb 25, 2023, 01:47:35

Data Sources of Route 2001:500:a8::/48 - 57695 137409 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update ↓
Code BGP Monitor		103.170.233.249	57695	Tokyo	🇯🇵	Asia	Feb 25, 2023, 01:47:35
Code BGP Monitor		194.156.163.203	57695	Singapore	🇸🇬	Asia	Feb 25, 2023, 01:47:35

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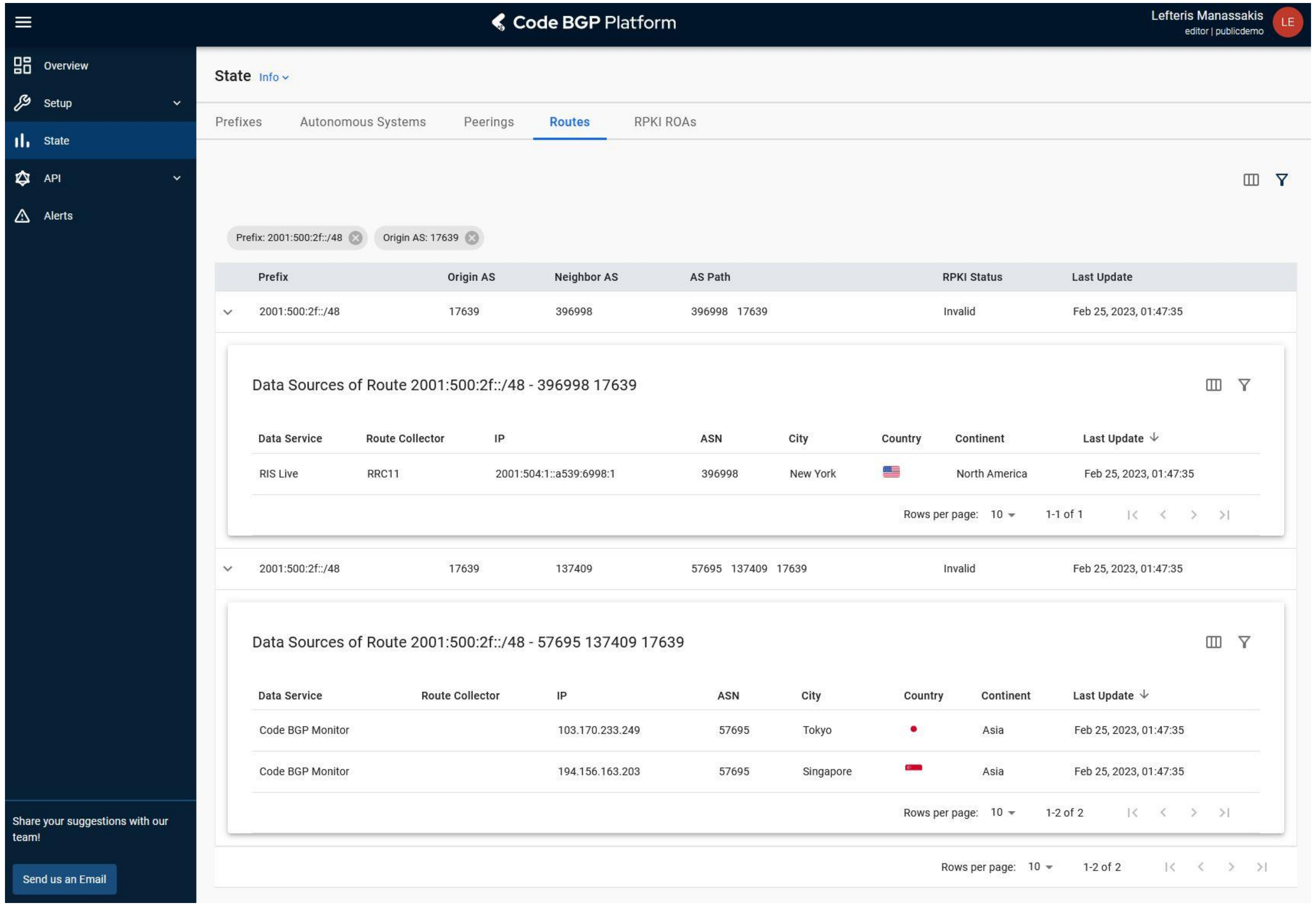
Rows per page: 10 1-5 of 5

Exact Prefix Hijacks detected for root DNS prefixes - Feb. 25

- The “F-Root” 2001:500:2f::/48 prefix is covered by a RPKI ROA. The event lasted 18 hours



Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:2f::/48	17639	396998	396998 17639	Invalid	Feb 25, 2023, 01:47:35

Data Sources of Route 2001:500:2f::/48 - 396998 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update
RIS Live	RRC11	2001:504:1::a539:6998:1	396998	New York	🇺🇸	North America	Feb 25, 2023, 01:47:35

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Prefix	Origin AS	Neighbor AS	AS Path	RPKI Status	Last Update
2001:500:2f::/48	17639	137409	57695 137409 17639	Invalid	Feb 25, 2023, 01:47:35

Data Sources of Route 2001:500:2f::/48 - 57695 137409 17639

Data Service	Route Collector	IP	ASN	City	Country	Continent	Last Update
Code BGP Monitor		103.170.233.249	57695	Tokyo	🇯🇵	Asia	Feb 25, 2023, 01:47:35
Code BGP Monitor		194.156.163.203	57695	Singapore	🇸🇬	Asia	Feb 25, 2023, 01:47:35

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Rows per page: 10 1-2 of 2

Prefix Hijacking Demo

Code BGP Platform

Questions

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🌐 codebgp.com