

# Let's talk about routing security

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How secure is our routing infrastructure in 2019?

# Fundamentals of global routing

1. Fundamentals of global routing
2. IRR
3. Present statistics
4. Future

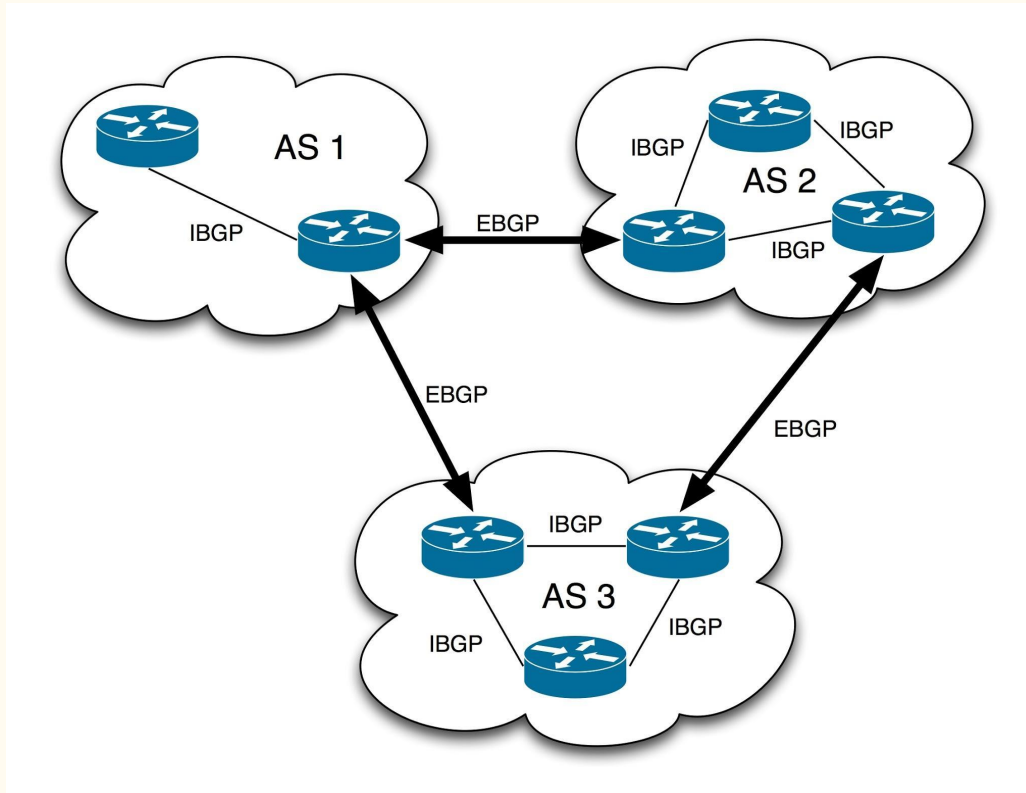
# Fundamentals of global routing...

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# Internet - Network of ASNs...

- Internet is simply network of autonomous networks all connected together and speaking “BGP”.
- There are around 65k autonomous networks (known by their number called ASN) in IPv4 routing and 17k ASNs in IPv6 world.
- A set of around 15 networks stitch these ASNs together by forming a “default free / transit free zone” and essentially all ASNs in the world are direct/indirect customer of either of these ASNs.
- A large part of modern traffic flows from a limited set of ASNs (content networks) to eyeball networks via PNI’s and Internet Exchanges

# Internet - Network of ASNs...



# Internet - Network of ASNs...(+ DNS!)

- BGP ensures interconnection of networks and DNS ensures domain to IP mapping.
- DNS relies on set of 13 logical root DNS servers and practically as many as 980 instances across the world via anycast.
- These 13 root DNS addresses are hardcoded in DNS resolver software (like BIND, powerdns etc) and hence security of these 13 IPs is important.
- DNS resolver contacts either of 13 based on reply time and other factors in the resolution algorithm.

So how “trust” in the  
BGP works?

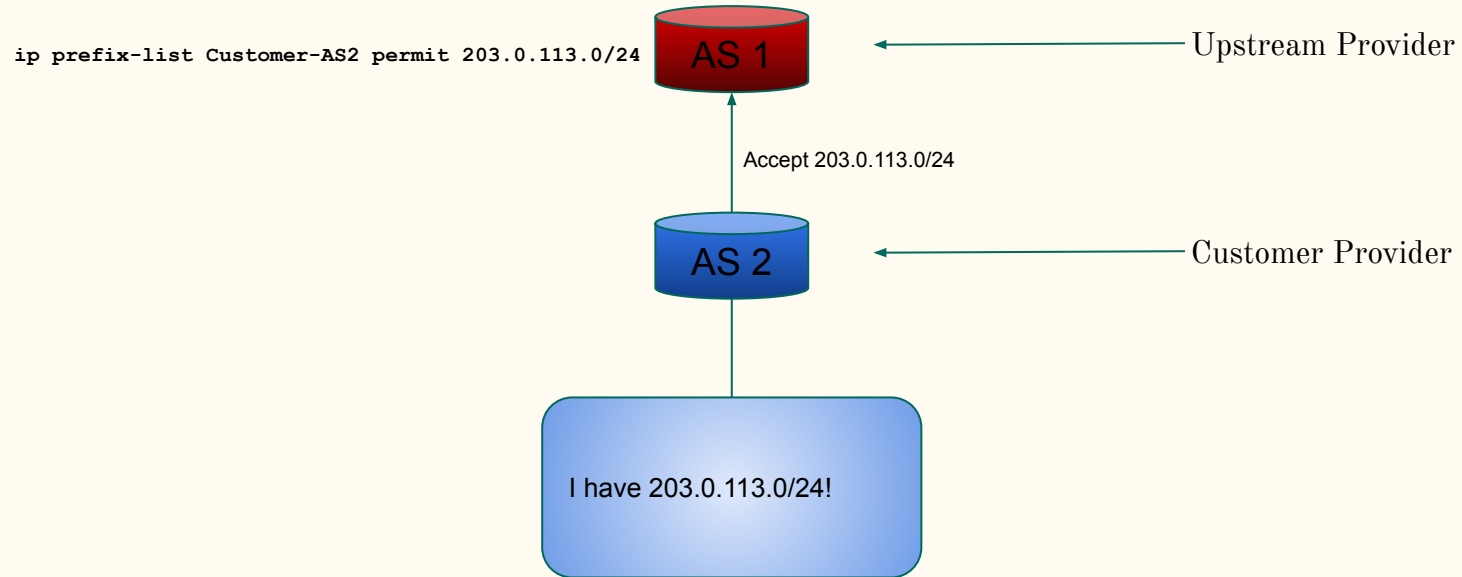
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# Trust in the BGP...

- BGP supports filtering and networks can define in filter what they can accept or reject and the default action (accept/reject).
- Filters can be based on IP prefix, ASN or AS Path or other factors like BGP community.
- Edge filtering - Filter the networks which connect to you based on static filter based on prefix and some other basic rules and full stop.
- Filtering beyond the edge - Allow prefixes of your downstream customer + their downstream + further their downstream and so on...

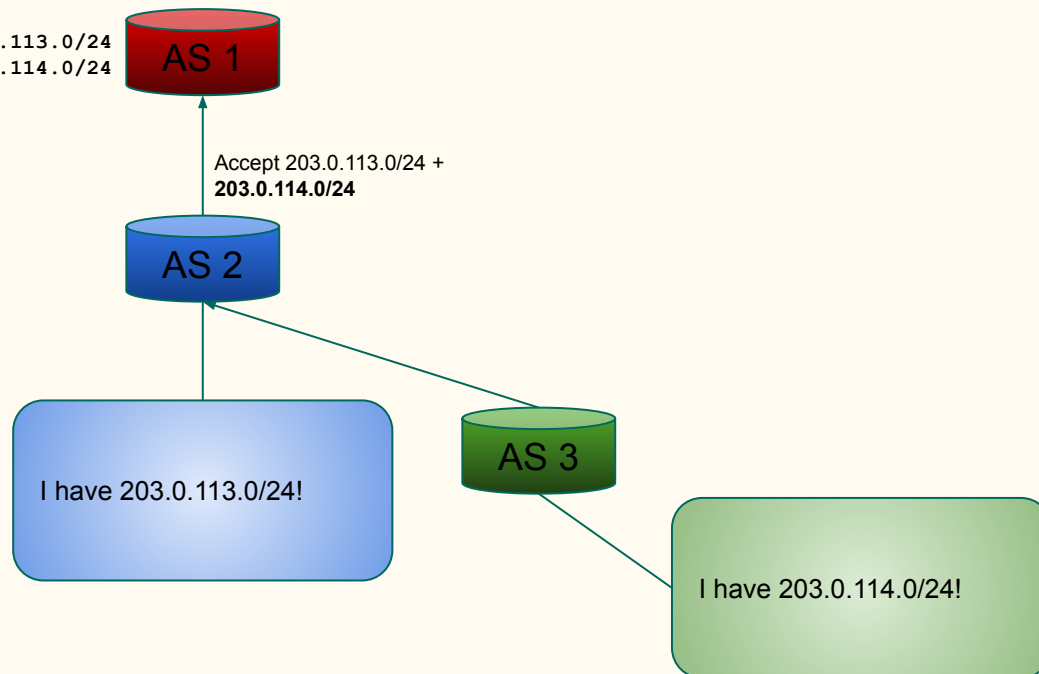


# Filtering chain...

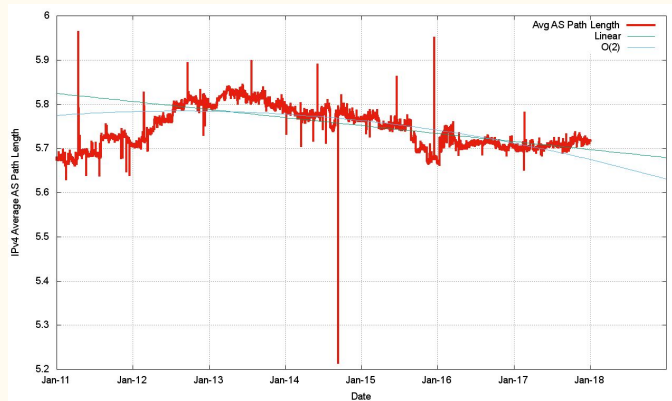


# Filtering chain...

```
ip prefix-list Customer-AS2 permit 203.0.113.0/24  
ip prefix-list Customer-AS2 permit 203.0.114.0/24
```



# Trust in the BGP...



As per research data by Mr Geoff Huston (Scientist at APNIC) average AS path length in IPv4 world is around 5.7 and hence for a case like  $AS\ 1 < AS2 < AS3 < AS4 < AS5$  it's very hard for AS1 to what to allow for AS4 (learnt via AS2).

How does filtering works at  
the “Internet scale” ?

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# IRR

1. Fundamentals of global routing
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-

# IRR - Internet Routing Registries

- IRRs are the public “registers” where one can log what they want to do and then just do it.
- IRRs use RPSL (Routing Policy Specific Language) to define “route object” where one defines prefix, origin AS, description etc and upstream can generate filters based on that.
- IRRs use “AS SETs” which define ASNs in a set (for instance a set of customer ASNs) and that is used to define customers ASNs.
- AS SETs can further have AS Sets of customer and that helps to generate downstream’s downstream’s downstream filter.

# IRR - Route Object Example

```
whois -h whois.radb.net 216.218.128.0/17
```

```
route:      216.218.128.0/17
descr:      Hurricane Electric
             55 South Market St
             San Jose, CA
origin:      AS6939
notify:      noc@he.net
changed:     noc@he.net 20170407
mnt-by:      HE-NOC
source:      RADB
```

# IRR - Route Object Example

```
whois -h whois.radb.net 216.218.128.0/17
```

```
route:      216.218.128.0/17    <- Prefix
descr:      Hurricane Electric
             55 South Market St
             San Jose, CA
origin:     AS6939      <- Origin AS
notify:     noc@he.net
changed:    noc@he.net 20170407
mnt-by:     HE-NOC
source:     RADB
```



# IRR - AS SET Example

```
whois -h whois.radb.net AS-ACT
```

```
as-set:          AS-ACT
descr:          ACT-AS
country:        IN
members:        AS55577, AS131269, AS131219,
AS18209,AS45196,AS24309,AS13335,AS138318
tech-c:         TB103-AP
admin-c:        AB208-AP
mnt-by:         MAINT-IN-BEAMTELECOM
mnt-lower:      MAINT-IN-BEAMTELECOM
last-modified:  2019-01-23T18:04:59Z
source:         APNIC
```

# More on Internet Routing Registries

- There are as many as 25 IRRs and were created for different reasons historically.
- Non-for profit RADB used mostly by larger organisations, free option ALTDB (for general Internet).
- One can define which IRR one is using at the peeringdb e.g RADB::AS-HURRICANE for Hurricane Electric or APNIC::AS9498:AS-BHARTI-IN for Airtel.
- RADB mirrors all major IRRs and thus a query to RADB includes it's own database as well as data of other mirrors IRRs.

# Query to RADB...

```
whois -h whois.radb.net 59.145.135.0/24

route:          59.145.135.0/24
descr:         BHARTI-IN
descr:         Bharti Airtel Limited
descr:         Class A ISP in INDIA .
descr:         234 , OKHLA PHASE III ,
descr:         NEW DELHI
descr:         INDIA
country:       IN
origin:        AS9498
mnt-by:        MAINT-IN-BBIL
changed:       rar.data@airtel.in 20070814
source:        APNIC
```

# Query to RADB...

```
whois -h whois.radb.net 59.145.135.0/24
```

```
route:          59.145.135.0/24
descr:          BHARTI-IN
descr:          Bharti Airtel Limited
descr:          Class A ISP in INDIA .
descr:          234 , OKHLA PHASE III ,
descr:          NEW DELHI
descr:          INDIA
country:        IN
origin:         AS9498
mnt-by:         MAINT-IN-BBIL
changed:        rar.data@airtel.in 20070814
source:        APNIC <- Shows the source database
```

# bgpq3 - Tool for generating filters

- Open source tool bgpq3 can be used for generating filters based on IRR.
- It supports syntax of Cisco, JunOS out of the box.
- It also supports generating filter list based on custom syntax (including JSON) of any given hardware.
- Includes supports for AS Path based filters as well as filters for IPv6 world.
- Supports only generation of filters and one needs to have a mechanism to push these filters to the routers.

# bgpq3 - in action

```
bgpq3 -l Anurag AS58901 -6
no ipv6 prefix-list Anurag
ipv6 prefix-list Anurag permit 2402:b580::/32
ipv6 prefix-list Anurag permit 2402:b580:1::/48
ipv6 prefix-list Anurag permit 2402:b580:2::/48
ipv6 prefix-list Anurag permit 2402:b580:3::/48
```

```
bgpq3 -J -l Anurag AS58901 -6
policy-options {
  replace:
    prefix-list Anurag {
      2402:b580::/32;
      2402:b580:1::/48;
      2402:b580:2::/48;
      2402:b580:3::/48;
    }
}
```

# bgpq3 - in action

```
bgpq3 -l Anurag AS58901 -6
no ipv6 prefix-list Anurag
ipv6 prefix-list Anurag permit 2402:b580::/32
ipv6 prefix-list Anurag permit 2402:b580:1::/48
ipv6 prefix-list Anurag permit 2402:b580:2::/48    <- Cisco iOS style syntax
ipv6 prefix-list Anurag permit 2402:b580:3::/48
```

```
bgpq3 -J -l Anurag AS58901 -6
policy-options {
replace:
  prefix-list Anurag {
    2402:b580::/32;
    2402:b580:1::/48;    <- JunOS syntax
    2402:b580:2::/48;
    2402:b580:3::/48;
  }
}
```

# It's querying RADB and formatting

```
whois -h whois.radb.net '!6as58901'  
A66  
2402:b580:1::/48 2402:b580:3::/48 2402:b580:2::/48 2402:b580::/32  
C
```

More on this on RADB here: <https://www.radb.net/query/help>



So how well IRR based  
filtering works?

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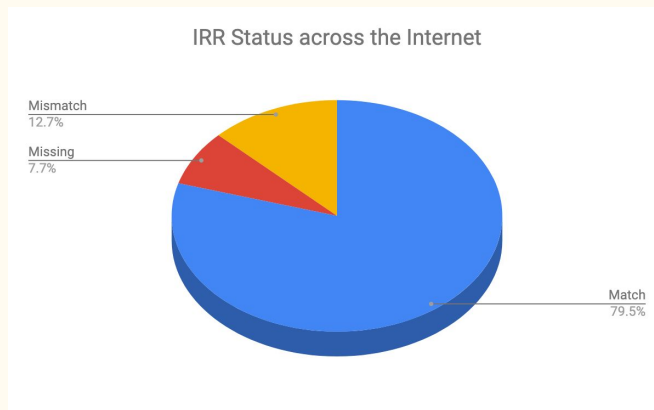
So how well IRR based  
filtering works? < - *Not so well!*

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# Present statistics

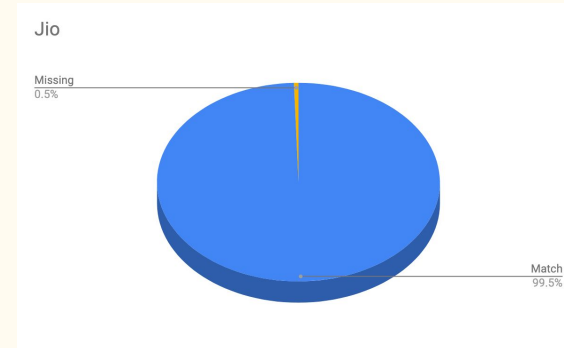
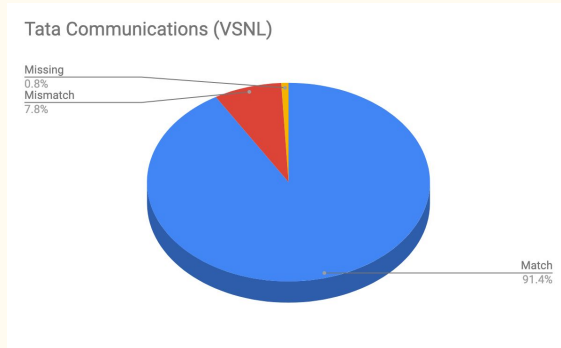
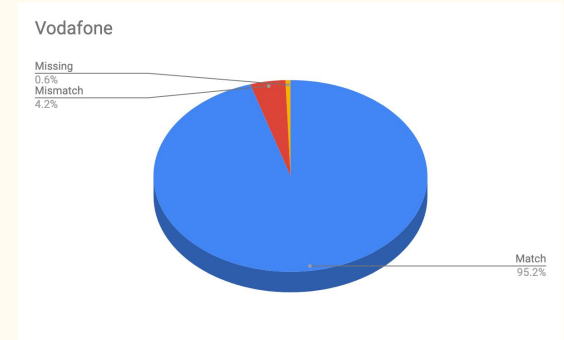
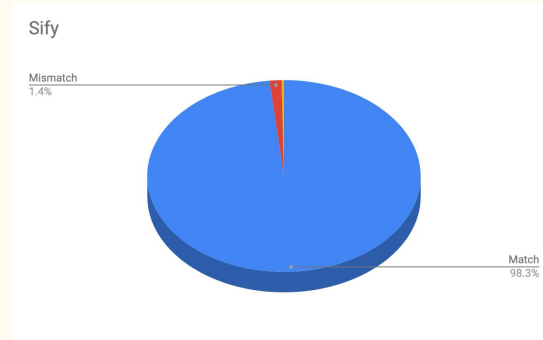
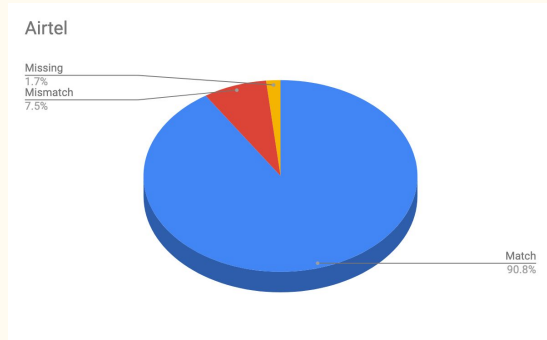
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# Filtering Statistics across the Internet



- There are as many as 758313 prefixes visible in global routing table (IPv4 + IPv6)
- Out of total routes: 603185 (79.54%) have valid route objects, 58587 (7.73%) have no valid route objects and 96514 (12.73%) have mismatching route object.
- Thus IRR based filtering can filter/blackhole 155101 routes or 20.45% of the total routes in the global table.

# Indian Networks IRR Status



Is there a real world problem  
here?

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# Last “few” route leaks/hijacks

1. YouTube route hijack by PTCL, Pakistan in 2008 -  
<https://www.cnet.com/news/how-pakistan-knocked-youtube-offline-and-how-to-make-sure-it-never-happens-again/>
2. Google’s route leak by Airtel in 2015 -  
<https://arstechnica.com/information-technology/2015/03/indian-isps-routing-hiccup-briefly-takes-google-down-worldwide/>
3. BGP/DNS Hijacks Target Payment Systems in 2018 -  
<https://hub.dyn.com/dyn-research/bgp-dns-hijacks-target-payment-systems-2>
4. Large European Routing Leak Sends Traffic Through China Telecom -  
<https://blogs.oracle.com/internetintelligence/large-european-routing-leak-sends-traffic-through-china-telecom>
5. And many more!

# Challenges with IRR based filtering

- IRR is old and not very easy to integrate with the routers.
- IRRs by design are log books and whatever goes in there, usually stays in there. In other words they are full of old outdated route objects.
- There's no direct incentive for smaller networks to maintain their entries in IRR and once they go online without IRR entries, they join the list of networks without valid route objects.
- The “software speaking to the routers & pushing config” isn't very common across smaller networks.



# Future

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# Some of developments in routing security...

- Folks who are filtering: Hurricane Electric (IRR), BharatIX (IRR + RPKI), Google (based on IRR starting in Sept 2019), AT&T (based on RPKI since Nov 2018), DECIX, INEX, Equinix Singapore IX etc.
- RPKI is being pushed for to use cryptography to validate prefix origin and is supported in latest version of various vendors. For supported hardware, it's very easy to implement in a route-map / routing-policy.
- RPKI is being integrated in next version of IRR (IRR 4) to ensure route objects cannot be created where ROA mismatch happens.

# RPKI in action...

```
router bgp 58901

  address-family ipv4 unicast
  neighbor 1.2.3.4 route-map Customer-IN in
  bgp bestpath prefix-validate allow-invalid
  !
  route-map Customer-IN permit 10
  match rpki invalid
  set local-preference 50
  !
  route-map Customer-IN permit 20
  match rpki not-found
  set local-preference 100
  !
  route-map Customer-IN permit 30
  match rpki valid
  set local-preference 200
  !
  route-map Customer-IN permit 40
```

# RPKI in action...






```
router bgp 58901

  address-family ipv4 unicast
  neighbor 1.2.3.4 route-map Customer-IN in
  bgp bestpath prefix-validate allow-invalid
  !
  route-map Customer-IN permit 10
  match rpki invalid
  set local-preference 50  <- Low localpref on route if RPKI check is invalid (Remember: High localpref wins)
  !
  route-map Customer-IN permit 20
  match rpki not-found
  set local-preference 100 <- Mid level localpref on route is no ROA is present
  !
  route-map Customer-IN permit 30
  match rpki valid
  set local-preference 200 <- High localpref when RPKI check is valid and route is preferred
  !
  route-map Customer-IN permit 40
```

Easy way to check IRR as  
well as RPKI for prefixes...

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# Check for IRR / RPKI ROA validation

- Hurricane Electric's BGP toolkit (free web tool!) supports both IRR as well as RPKI checks.
- Simply go to **bgp.he.net** and search with network name or AS number or prefix and you will see the status of prefixes.
-  Reflects when correct matching route object exists.
-  Reflects when parent route object exists (say for /17 or /21 etc when announcement is for /22).
-  Reflects when there is a mismatch of route objects.
-  Reflects when RPKI check is valid.
-  Reflects when RPKI check is invalid.

# Check for IRR / RPKI ROA validation

<u>104.20.128.0/20</u>	 	Cloudflare, Inc.	
<u>104.20.144.0/20</u>	 	Cloudflare, Inc.	
<u>104.20.160.0/20</u>	 	Cloudflare, Inc.	
<u>104.20.176.0/20</u>	 	Cloudflare, Inc.	

[https://bgp.he.net/AS13335#\\_prefixes](https://bgp.he.net/AS13335#_prefixes)

<u>49.206.204.0/22</u> 	Beam Telecom Pvt Ltd	
<u>49.206.208.0/22</u> 	Beam Telecom Pvt Ltd	
<u>49.206.212.0/22</u> 	Beam Telecom Pvt Ltd	
<u>49.206.216.0/22</u> 	Beam Telecom Pvt Ltd	
<u>49.206.220.0/22</u> 	Beam Telecom Pvt Ltd	

[https://bgp.he.net/AS18209#\\_prefixes](https://bgp.he.net/AS18209#_prefixes)

# Check for IRR / RPKI ROA validation

<a href="#">58.2.238.0/23</a>		Gecis- Global Business Organisation ,	
<a href="#">58.2.238.0/24</a>		Gecis- Global Business Organisation ,	
<a href="#">58.2.239.0/24</a>		Gecis- Global Business Organisation ,	
<a href="#">59.144.0.0/15</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.0.0/19</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.4.0/22</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.4.0/24</a>		TATA CONSULTANCY SERVICES	
<a href="#">59.144.6.0/24</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.8.0/21</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.8.0/24</a>		BHARTI INFOTEL LTD.	
<a href="#">59.144.9.0/24</a>		BANARAS HINDU UNIVERSITY	
<a href="#">59.144.10.0/24</a>		BHARTI INFOTEL LTD.	

[https://bgp.he.net/AS9498#\\_prefixes](https://bgp.he.net/AS9498#_prefixes)



# Contribute in the cleanup!

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# How can you contribute?

- If you maintain resources (IPv4, IPv6 or AS numbers) then ensure to register route objects for them in either of databases - database of your RIR (in India? Contact IRINN, in Asia - do via My APNIC portal, in US - use ARIN portal).
- Create ROAs with your origin ASN and prefix length you intend to announce.
- Report all incorrect IRR entries you encounter to those registries to help them in removing old junk.
- DO NOT register route object on behalf of someone as a proxy entry as that has been a bad practice.
- If you have downstream ASNs behind you, register a AS SET.
- Register yourself on peeringdb.com portal and remember to mention your AS SET in the IRR section.

# References

1. Tier 1 Networks Wikipedia Page - [https://en.wikipedia.org/wiki/Tier\\_1\\_network#List\\_of\\_Tier\\_1\\_networks](https://en.wikipedia.org/wiki/Tier_1_network#List_of_Tier_1_networks)
2. BGP Version 4 RFC - <https://tools.ietf.org/html/rfc4271>
3. Root DNS servers list/locations - <https://root-servers.org/>
4. BGP in 2017 (APNIC Blog) - <https://blog.apnic.net/2018/01/10/bgp-in-2017/>
5. RSPL - <http://www.irr.net/docs/rpsl.html>
6. bgpq3 - <https://github.com/snar/bgpq3>
7. Hurricane Electric's route filtering algorithm - <http://routing.he.net/algorithm.html>
8. Google route filtering announcement NANOG75 - [https://pc.nanog.org/static/published/meetings/NANOG75/1959/20190220\\_Morrow\\_Lightning\\_Talk\\_Prefix\\_v1.pdf](https://pc.nanog.org/static/published/meetings/NANOG75/1959/20190220_Morrow_Lightning_Talk_Prefix_v1.pdf)
9. IRR (present one) - <https://github.com/irrdnet/irrd>
10. IRR v4 (in development) - <https://github.com/irrdnet/irrd4>
11. AT&T drops RPKI invalid for peers - <https://mailman.nanog.org/pipermail/nanog/2019-February/099501.html>

# Questions/Comments?

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