Large Scale Internet Measurement Infrastructures

Challenges and Opportunities

Emile Aben | 2018-11 | Internet Conference
Key Internet Statistics

• Size: 510,072,000 km²

• Population: 4,208,571,287 (55.2% of world)

• Addresses:
  - IPv4: 4,294,967,296 (many unusable)

• Subunits:
  - Networks (ASNs): 62,408
  - IPv4 prefixes: 692k - 752k
  - IPv6 prefixes: 56k - 62k
How is it all Interconnected?

• Large vs small networks
  - AS4143 (106,187,232 IPv4 addresses)
  - 15,099 networks announcing a /24 (256 IPv4 addresses)

• Types of networks (user, content, transit, …)

• Means of interconnect: direct or IXP
Why do we Measure?

• "That which is measured improves. That which is measured and reported improves exponentially."  -- Karl Pearson
What is RIPE NCC?
RIPE Atlas

RIPE Atlas is a global, open, distributed Internet measurement platform, consisting of thousands of measurement devices that measure Internet connectivity in real time.
What is RIPE Atlas?

• Goal: Improve Internet through measurements

• Probes hosted by volunteers

  “For the community, by the community”

• Data publicly available

https://atlas.ripe.net/
RIPE Atlas Probes

• Regular probes (version 1,2,3)
  - Small form factor boxes

• RIPE Atlas anchors
  - 1U servers (Soekris)

• New: Virtual Anchors
Most Popular Features

• Six types of measurements: ping, traceroute, DNS, SSL/TLS, NTP and HTTP (to anchors)

• APIs and CLI tools to start measurements and get results

• Built-in Measurements
  • DNS Root servers
  • Probes to Anchors

• User-Defined Measurements
  • Probe owners can schedule, not only on their own probes!
Internet “Air Traffic Control”

- BGP makes Interdomain routing work
- Border routers: Routers that receive explicit routing information for all of the Internet

- How do we monitor this “air traffic control”?
- Listen in on this “chatter” at interesting places in the Internet?
Routing Data (RIS)

- 20 BGP collectors
- 600+ peers (150+ “full-feed”)
- Most at IXPs
## Example RRC06

### RRC06 -- DIX-IE, Tokyo, Japan -- Peer List

<table>
<thead>
<tr>
<th>Status</th>
<th>ASN</th>
<th>Description</th>
<th>Address</th>
<th>IPv4 prefixes</th>
<th>IPv6 prefixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>AS42</td>
<td>WOODYNET-1 - WoodyNet</td>
<td>202.249.2.183</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>Up</td>
<td>AS2497</td>
<td>IIJ Internet Initiative Japan Inc.</td>
<td>2001:200:0:fe00::9c1:0</td>
<td>0</td>
<td>56653</td>
</tr>
<tr>
<td>Up</td>
<td>AS2497</td>
<td>IIJ Internet Initiative Japan Inc.</td>
<td>202.249.2.169</td>
<td>721553</td>
<td>0</td>
</tr>
<tr>
<td>Up</td>
<td>AS3856</td>
<td>PCH-AS - Packet Clearing House</td>
<td>202.249.2.184</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Up</td>
<td>AS4777</td>
<td>APNIC-NSPIXP2-AS Asia Pacific Network Information Centre</td>
<td>2001:200:0:fe00::12a9:0</td>
<td>0</td>
<td>56717</td>
</tr>
<tr>
<td>Up</td>
<td>AS4777</td>
<td>APNIC-NSPIXP2-AS Asia Pacific Network Information Centre</td>
<td>202.249.2.20</td>
<td>726451</td>
<td>0</td>
</tr>
<tr>
<td>Up</td>
<td>AS25152</td>
<td>K-ROOT-SERVER - Reseaux IP Europeans Network Coordination Centre (RIPE NCC)</td>
<td>2001:200:0:fe00::6249:0</td>
<td>0</td>
<td>59300</td>
</tr>
<tr>
<td>Up</td>
<td>AS25152</td>
<td>K-ROOT-SERVER - Reseaux IP Europeans Network Coordination Centre (RIPE NCC)</td>
<td>202.249.2.185</td>
<td>735164</td>
<td>0</td>
</tr>
</tbody>
</table>

IPv4 full tables: 3
IPv6 full tables: 3
Total peerings: 8
Data source time: 2018-11-14T08:00:00

[http://www.ris.ripe.net/peerlist/rrc06.shtml](http://www.ris.ripe.net/peerlist/rrc06.shtml)
Challenges and Opportunities
RIPE Atlas Bias

Collaborator: Petros Gigis, George Michaelson
Challenge: How biased is RIPE Atlas

• Opportunistic distribution of Internet vantage points

• Intuitively biased towards: netops, techie, Europe

• Can we measure this bias?
  - Identify redundancies - i.e. multiple probes with very similar view of the Internet
  - Identify where probes are missing
Challenge: RIPE Atlas Bias

Coverage

IPv4 ASNs covered
3555 (5.676%)

IPv6 ASNs covered
1439 (8.944%)

Number of countries covered
180 (91.837%)

<table>
<thead>
<tr>
<th>ASN (v4)</th>
<th>Probes</th>
<th>ASN (v6)</th>
<th>Probes</th>
<th>Prefix (v4)</th>
<th>Probes</th>
<th>Prefix (v6)</th>
<th>Probes</th>
<th>Country</th>
<th>Probes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3320</td>
<td>341</td>
<td>6939</td>
<td>250</td>
<td>73.0.0.0/8</td>
<td>130</td>
<td>2001:470::32</td>
<td>249</td>
<td>Germany</td>
<td>1411</td>
</tr>
<tr>
<td>7922</td>
<td>341</td>
<td>3320</td>
<td>247</td>
<td>79.192.0.0/10</td>
<td>61</td>
<td>2003::/19</td>
<td>247</td>
<td>United States of America</td>
<td>1131</td>
</tr>
<tr>
<td>6830</td>
<td>317</td>
<td>7922</td>
<td>194</td>
<td>87.128.0.0/10</td>
<td>52</td>
<td>2601::/20</td>
<td>174</td>
<td>France</td>
<td>857</td>
</tr>
<tr>
<td>3215</td>
<td>223</td>
<td>3215</td>
<td>138</td>
<td>84.128.0.0/10</td>
<td>50</td>
<td>2a01:e00::/26</td>
<td>100</td>
<td>United Kingdom</td>
<td>597</td>
</tr>
<tr>
<td>12322</td>
<td>210</td>
<td>12322</td>
<td>116</td>
<td>78.192.0.0/11</td>
<td>46</td>
<td>2002::/16</td>
<td>45</td>
<td>Netherlands</td>
<td>535</td>
</tr>
<tr>
<td>3265</td>
<td>103</td>
<td>3265</td>
<td>96</td>
<td>93.192.0.0/10</td>
<td>45</td>
<td>2a02:908::/33</td>
<td>38</td>
<td>Russia</td>
<td>463</td>
</tr>
<tr>
<td>701</td>
<td>94</td>
<td>6830</td>
<td>73</td>
<td>91.0.0.0/10</td>
<td>44</td>
<td>2001:980::/29</td>
<td>36</td>
<td>Italy</td>
<td>288</td>
</tr>
<tr>
<td>31334</td>
<td>87</td>
<td>8881</td>
<td>57</td>
<td>83.160.0.0/14</td>
<td>36</td>
<td>2001:8b0::/32</td>
<td>35</td>
<td>Switzerland</td>
<td>273</td>
</tr>
<tr>
<td>33915</td>
<td>81</td>
<td>31334</td>
<td>51</td>
<td>88.176.0.0/12</td>
<td>35</td>
<td>2001:980::/32</td>
<td>34</td>
<td>Czechia</td>
<td>259</td>
</tr>
<tr>
<td>5089</td>
<td>78</td>
<td>20712</td>
<td>37</td>
<td>109.190.0.0/16</td>
<td>34</td>
<td>2a02:a000::/26</td>
<td>34</td>
<td>Canada</td>
<td>222</td>
</tr>
</tbody>
</table>
Opportunity: Probes vs Eyeballs

http://sg-pub.ripe.net/petros/population_coverage/country.html?name=JP
http://sg-pub.ripe.net/petros/population_coverage/country.html?name=KR
RIPE Atlas Vantage
Point Selection

Collaborators: Thomas Holtenbach, Cristel Pelsser, Randy Bush, Laurent Vanbever
Challenge: Where to Measure From?

- 10k RIPE Atlas probes
- Select by: Country, ASN

- 10 probes from Uruguay vs. 10 probes from Ukraine?

- Other ways to find diversity/uniformity in measurement sources?
Probe Similarity

• How (dis)similar are RIPE Atlas vantage points?

• Goal: Optimise what you discover with as little vantage points as possible

• Means: Pairwise similarity metric
Probe Similarity

- 25% more IPs seen when picking dissimilar probes vs default

- Other similarities:
  - DNS similarity
  - RTT
  - Outages (physical infrastructure/electricity)

10% of probes have “identical IPv4 twin(s)”
RIPE Atlas Bulk Data Analysis

Collaborator: Petros Gigis
Bulk Data Downloads

- [https://data-store.ripe.net/datasets/atlas-daily-dumps](https://data-store.ripe.net/datasets/atlas-daily-dumps)
- [https://labs.ripe.net/Members/petros_gigis/announcing-daily-ripe-atlas-data-archives](https://labs.ripe.net/Members/petros_gigis/announcing-daily-ripe-atlas-data-archives)
Challenge: Big Data Analysis

- Using all of RIPE Atlas traceroutes
- What’s the bias?

Large IXP Outages

https://labs.ripe.net/Members/emileaben/does-the-internet-route-around-damage
https://labs.ripe.net/Members/emileaben/does-the-internet-route-around-damage-in-2018
Countering Bias

- Useful step up from many other analysis already
  - but not enough!

- Challenge: per AS / per eyeballs / per IXP member share / Other?
RIPE Atlas: Traceroute
IP Geolocation

In collaboration with CAIDA
Challenge: IP Geolocation

- Often thought of as a “solved problem”
- Edge geolocation is generally “ok”
- Infrastructure (routers, servers) IP geolocation much worse than edge
Opportunity: IPmap

- IPmap: collaborative approach to IP geolocation: https://ipmap.ripe.net/
- Multiple ‘engines’, e.g.
  - Crowdsourcing
  - RTT triangulation with RIPE Atlas
  - Anycast

- Open challenge: How to best combine multiple engine results?
RIPE Atlas: Interconnect with a Region

Collaborators: Petros Gigis, Daniele Arena, George Michaelson
Opportunity: Characterise Interconnect

• Does Internet traffic stay local?
  - default: local = within country borders
  - other: sets of countries, cities, custom sets of probes

• Do IXPs help?

• IXP-country-jedi is a measurement method and set of visualisations that provide insight

https://www.ripe.net/ixp-country-jedi
Opportunity: ixp-country-jedi

• Mesh of traceroutes within a country

• Example viz: IXP-country matrix
  - green: stays in country

Albania  Ireland  Japan
IXP-country-jedi: Geo Viz

Albania

Ireland

Japan
IXP-country-jedi: Geo Viz
How Are End Users Interconnected?

http://sg-pub.ripe.net/ixp-country-jedi/
How Are End Users Interconnected?

Belgium

http://sg-pub.ripe.net/ixp-country-jedi/
How Are End Users Interconnected?

Belgium

The size of the circle indicates the in-betweenness of the network IXP.

Size of ring segment is a measure for the amount of end users in the network.

End users network

Transit provider

http://sg-pub.ripe.net/ixp-country-jedi/
How Are End User Interconnected?

http://sg-pub.ripe.net/ixp-country-jedi/jp/2018/10/01
RIPE Atlas: Ethics in Measurement
Ethical Design Decisions

• Low, cheap barrier of entry
• Active measurements only
  - No passive measurements
  - Probes do not observe user traffic
• Data, API, source code, tools: free and open
• Set of measurement types limited
  • In order to prevent putting probe hosts at risk


https://fosdem.org/2017/interviews/vesna-manojlovic/
Ongoing Moral Dilemmas

• 2013: Opening-up source code

• 2014: Keeping “non-public” measurements

• 2015: Not allowing HTTP measurements to random targets

• 2016: Security audit and pen-testing
Strong Community Involvement

• Active mailing list (ripe-atlas@ripe.net)
  - Passionate discussions

• HTTP measurements only towards RIPE Atlas anchors
  - https://labs.ripe.net/Members/kistel/ethics-of-ripe-atlas-measurements

• Responsible disclosure (bug reports)
Opportunity: DNS resolution

- NLNetLabs project: DNSThought
- Started at a hackathon we organised

https://dnsthought.nlnetlabs.nl/
RIPE RIS: Zombie Routes?

Collaborator: Romain Fontugne
Challenge: Is A Route Withdrawn?

- Zombie Routes: Routing table entries for routes that are withdrawn from origin

After 3072 hours of manipulating BGP, @JobSnijders has succeeded in drawing a Nyancat on the RIPE statmon interface. tinyurl.com/nyancatbgp
Challenge: Is A Route Withdrawn?

• Zombie Routes: Routing table entries for routes that are withdrawn from origin
Example: Long Lived

Tons of BGP updates
Route totally withdrawn only after manual intervention

3 Months!

Confusing if you want to know: Is this routed publicly?
BGP Beacons

Current RIS Routing Beacons

Note: IPv6 beacons and anchors are now being announced from the RRCs. See below for details.

All RRCs:
- Announcements at 00:00, 04:00, 08:00, 12:00, 16:00, 20:00 (UTC)
- Withdrawals at 02:00, 06:00, 10:00, 14:00, 18:00, 22:00 (UTC)
BGP Beacons

Current RIS Routing Beacons

Note: IPv6 beacons and anchors are now being announced from the RRCs. See below for details.

All RRCs:

- Announcements at 00:00, 04:00, 08:00, 12:00, 16:00, 20:00 (UTC)
- Withdrawals at 02:00, 06:00, 10:00, 14:00, 18:00, 22:00 (UTC)
**BGP Beacons**

**Current RIS Routing Beacons**

*Note:* IPv6 beacons and anchors are now being announced from the RRCs. See below for details.

**All RRCs:**
- Announcements at 00:00, 04:00, 08:00, 12:00, 16:00, 20:00 (UTC)
- Withdrawals at 02:00, 06:00, 10:00, 14:00, 18:00, 22:00 (UTC)

Visibility for prefix 84.205.67.0/24 (full feed RIS peers)
BGP Zombies Conclusions

• Made us look hard and long at our infrastructure

• Existence is commonly known among netops
  - Hard to debug

• One vendor identified by operator, but needs proof of incorrect behaviour
RIPE RIS: Bias?

Collaborator: Romain Fontugne
How Important is network X for you?
Counter Bias with AS Hegemony

- Remove bias with trimmed averaging
  - “AS Hegemony” scores

https://ihr.iijlab.net/ihr/
RIPE RIS: Outages

Collaborator: Collin Anderson
RIS Outage Detection

https://github.com/emileababen/resource-gnuplotter

Even better: Combine with Atlas!

RIPE RIS: Tracking Technology Deployment
Longitudinal view

- Tracking IPv6: https://v6asns.ripe.net/
Tracking Large BGP Communities

https://labs.ripe.net/Members/emileaben/bgp-large-communities-uptake-by-the-community-at-large
But ... The Main Challenge/Opportunity?
Main Challenge/Opportunity

• Many challenges and opportunities around RIPE Atlas and RIPE RIS

• Main Opportunity:

  Collaboration

• We are open to collaborate
Collaboration Possibilities

• We can help:
  - Understand/analyse data
  - Schedule (large scale) measurements
  - Collaborate on projects

• Open Code (Github) / Open Data

• Communication with Internet community
  - https://labs.ripe.net/ / RIPE meetings / RACI

• Hackathons: https://labs.ripe.net/hackathons

• Students/Internships
Questions

emile.aben@ripe.net  
not a typo  
twitter: @meileaben  
mastodon: @meileaben@vis.social  
not a typo