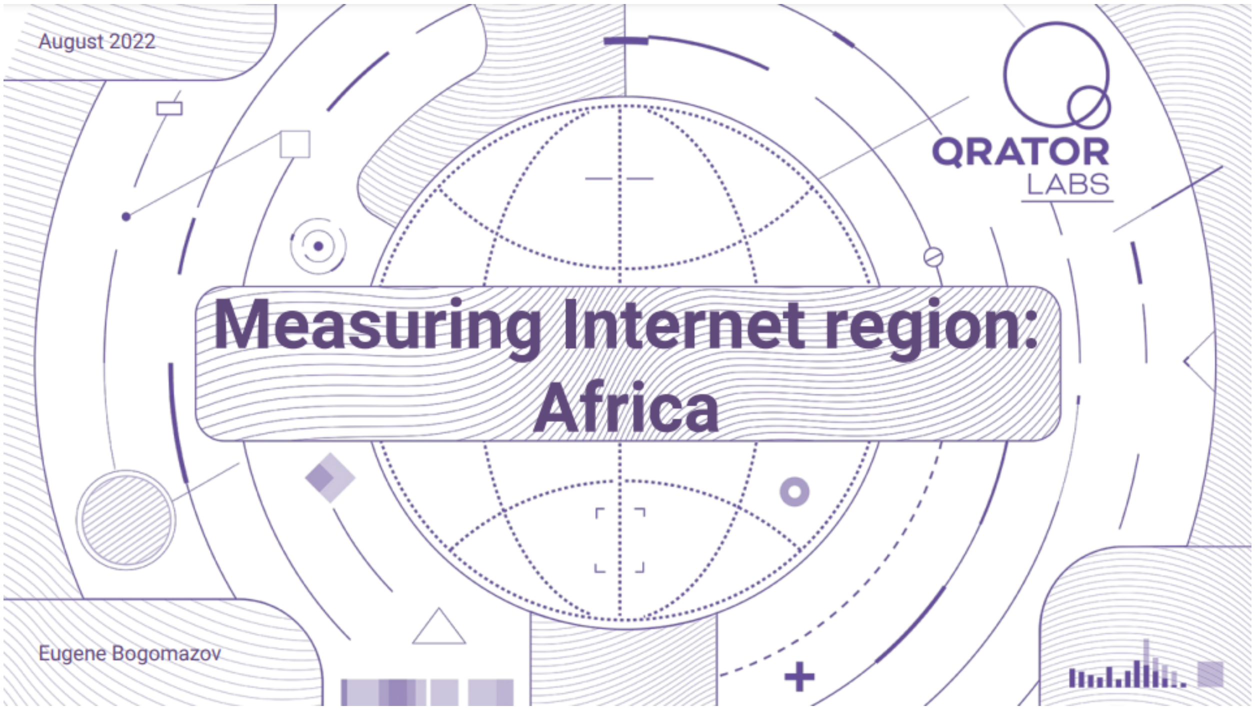


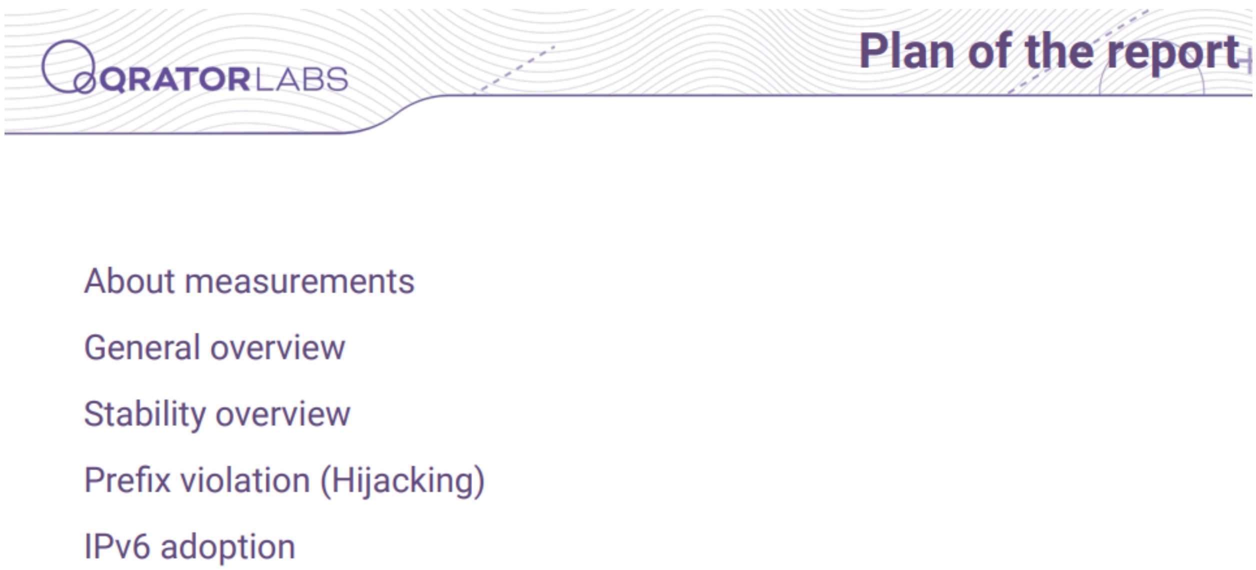
Eugene Bogomazov from Qrator Labs presented a paper during the African Peering and Interconnection Forum that took place on August 23, 2022. The paper highlights the results and conclusions of measurements taken from several networks in African countries. We publish these results here through this blog.

In this research, Qrator.Radar team evaluated the African Internet segment and its current state: how many ISPs operate in the region and their state of affairs. Also, research highlights routing security metrics, as well as transit reliability.

The video of this presentation is also available at
https://livestream.com/internetsociety/afpif2022/videos/232635696.

First of all - why do we care? I work for Qrator Labs, a DDoS attacks mitigation company, and we have our own BGP anycast network. Also, I represent the Qrator.Radar project, where we have a BGP collector with more than 800 points of presence - so we have the BGP data to create a BGP monitoring tool, and also it allows us to conduct further network research.

Lastly, as Qrator.Radar, we participate in the IETF activity to make the BGP protocol more secure and safe.



What will this presentation be about? First, we will discuss our measurements: what and how we are trying to measure.

Then we'll look at a few simple yet powerful general metrics we've chosen to highlight. After that, we will consider the specific metrics of the stability of the region's network in the event of a single point of failure. Later we will discuss some of the BGP incidents, particularly how often BGP attackers violate your address space. Finally, we will try to figure out what happens when you enter the IPv6 world.

First, let's talk about what we are trying to measure.

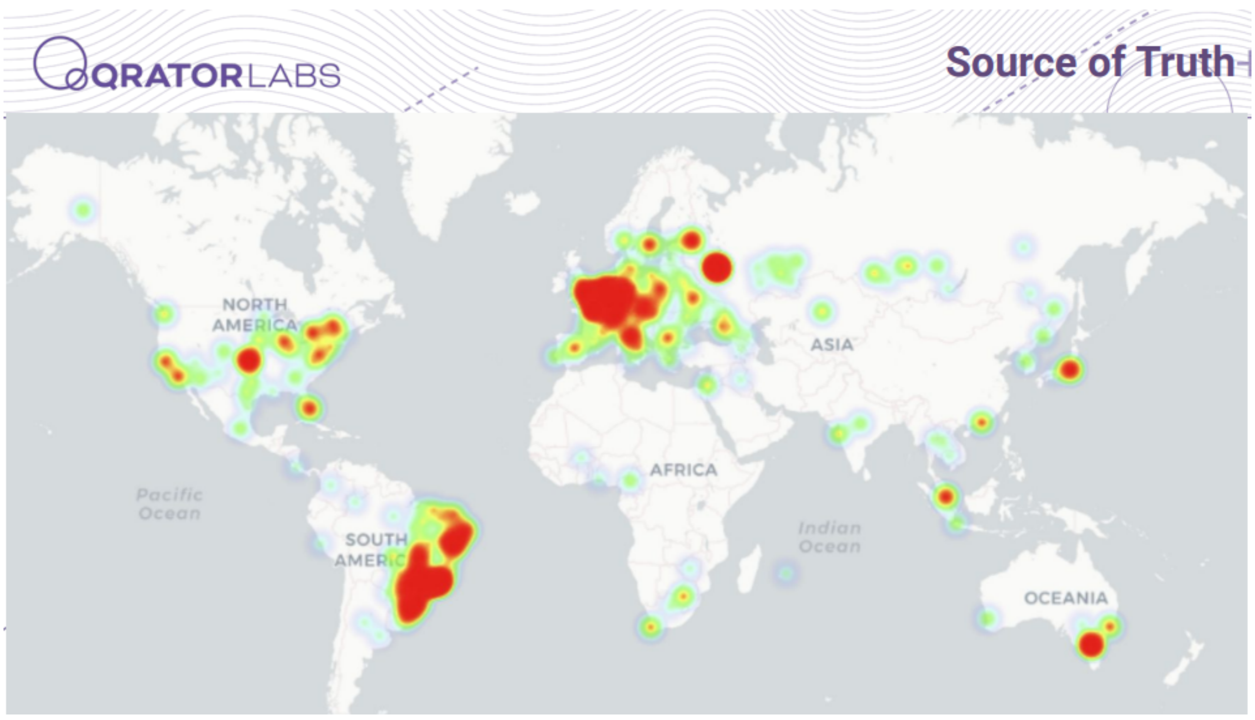
About measurements

How to measure – what data sources to use for measurements

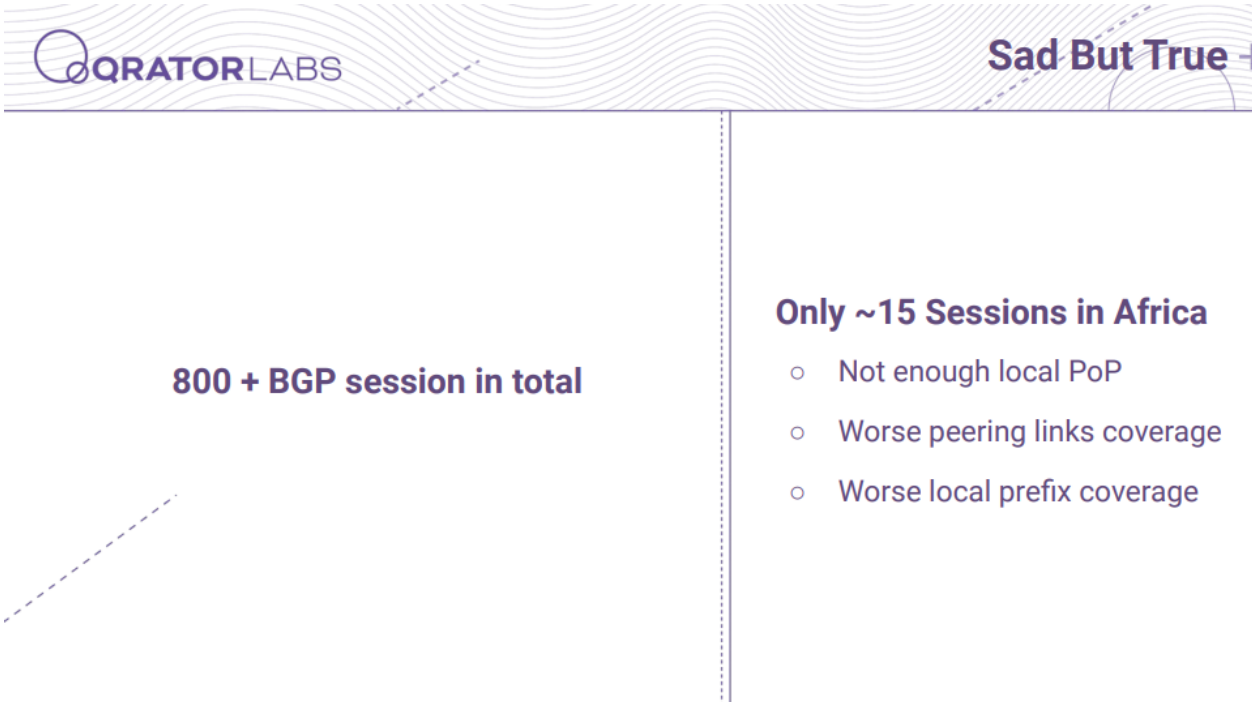
What to measure – what algorithm to use

How to visualize – what aspects we want to study

Our measurements consist of separate parts. First, we discuss what data sources we are using; second, we discuss what algorithm we are using and what the pitfalls are that could happen, and we will show the results of some of those pitfalls. And finally, we will visualize our findings.



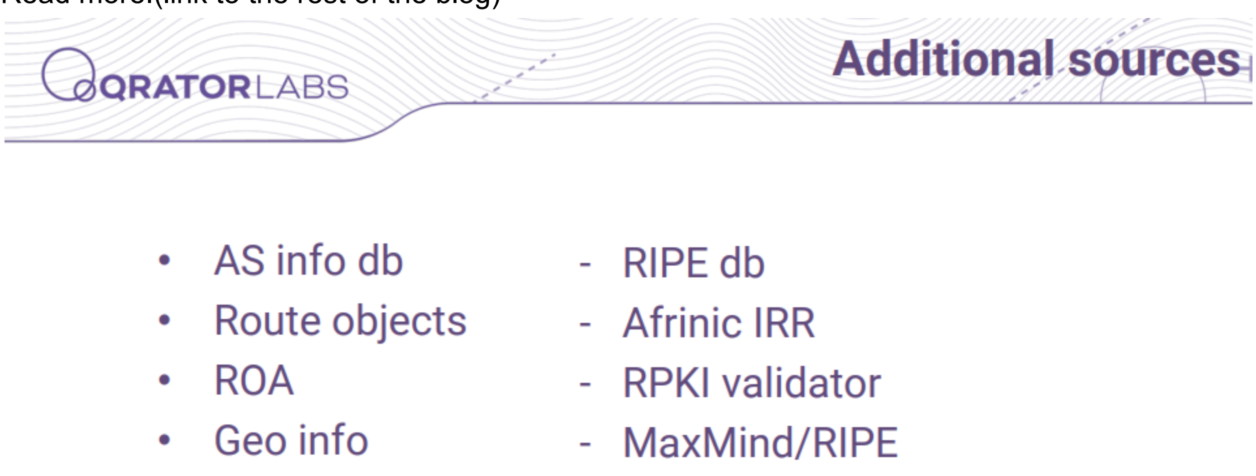
As I mentioned, we have our own BGP collector, and you can see all our observation points on this heatmap. This BGP data is the primary source which allows us to make conclusions and conduct research. And I think you already see a little problem with this map - even if we have several hundreds of BGP sessions, we have only 15 observation points in Africa.



So, what is the problem? In Africa, there are around 50 IXPs, and many local routes can be seen only on these IXes; they don't traverse to the Tier-1s and, therefore, to different parts of the world. We (in Qrator.Radar) can't see these routes as we don't see local peering and thus do not consider such peering links at the later steps.

But we could use what we have, and so we will use related data from other parts of the world.

Read more.(link to the rest of the blog)



Also, when talking about BGP data, we see prefixes and AS paths. So, to get a description of ASNs, we use IRR databases. To obtain information about to which country a given ASN or prefix belongs, we use geo community services such as MaxMind and others. And when we are talking about prefix violations, there are two types of objects indicating legitimate owners of the address spaces: Afrinic IRR for route objects and RPKI storage for RPKI/ROA objects.

QRATOR LABS

Ranking

100+ different ways

** If we consider only graph ranking*

When we talk about ranking, we have a problem. Because the network is a graph, there are too many ways to figure out which nodes in the graph are important. Therefore, we need to find a subset of these metrics, that is, from one point of view, simple enough to understand but, from another point of view, powerful enough to describe what is happening with the region as a whole.

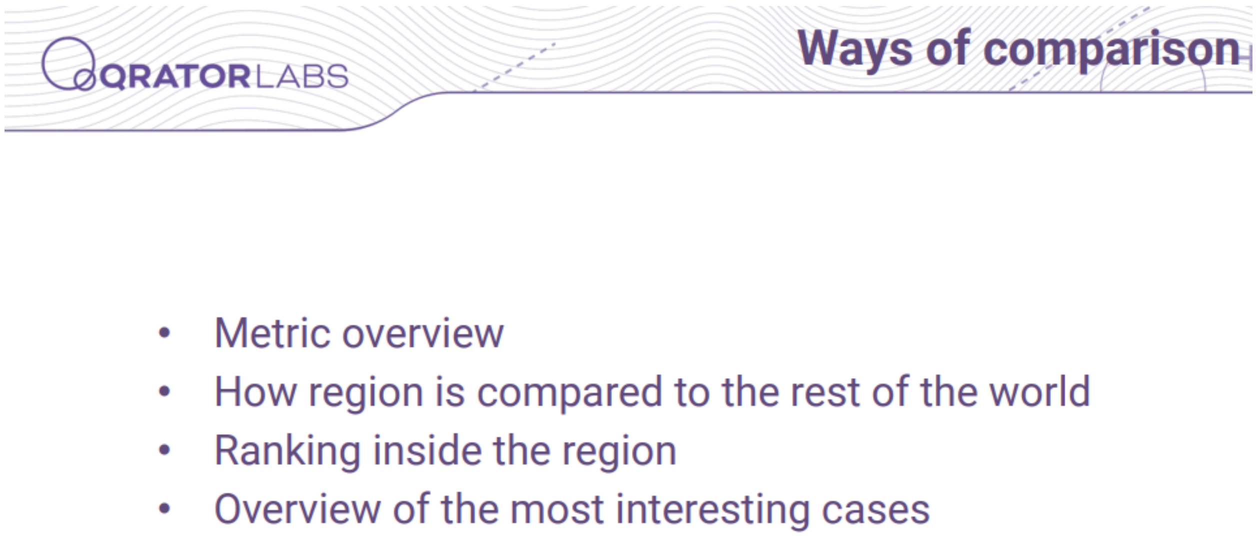
QRATOR LABS

What to Measure

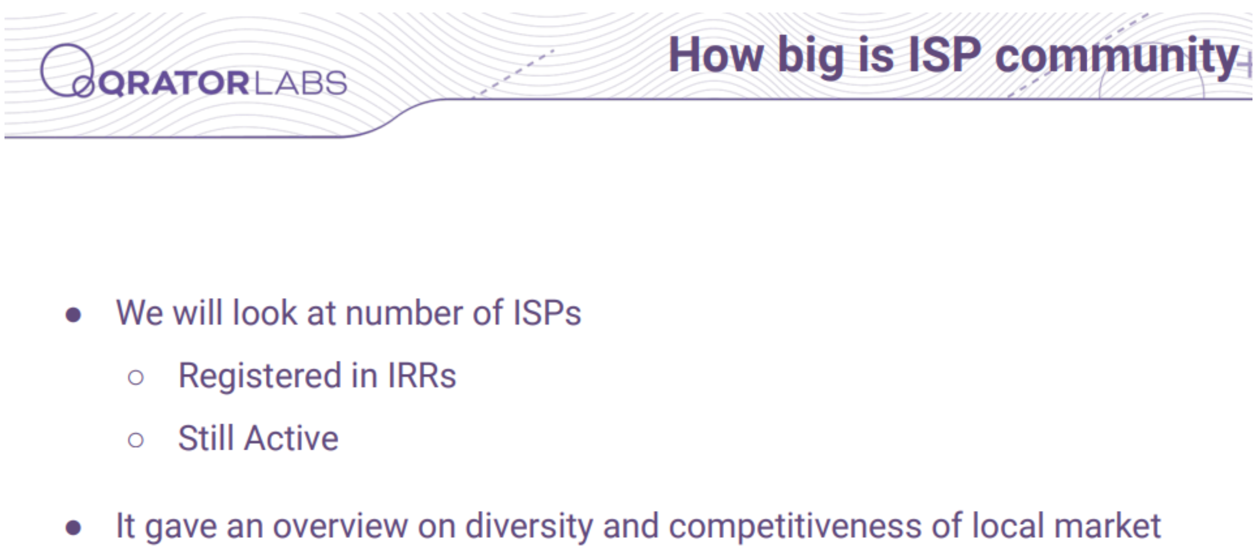
There is no universal and best rating system

- You can choose measurements that have a logical explanation
  - And add weights to the nodes
- Or create your own measurements

First, we'll look at the most common ones, present our metrics, and describe what they are measuring and why they are essential.



Let's take a look at the general metrics.



When talking about what is happening in a region, the first question that comes to mind is how many ISPs are there in a country or region. You can obtain this metric from different angles. First, you can find out how many ASNs are registered in the Afrinic IRR or, for example, gather all BGP routes, correlate how many of them are being announced by local ISPs and thus find out how many of them are alive.

QRATOR LABS

General Overview...

		#Registered ASNs			#Announced ASNs			#Announced Prefixes		
iso	name	Value	Percentage	Place	Value	Percentage	Place	Value	Percentage	Place
US	United States	29499	27.39%	1	17915	24.28%	1	305483	27.44%	1
BR	Brazil	8946	8.30%	2	8150	11.04%	2	97251	8.74%	2
RU	Russian Federation	5893	5.47%	3	5029	6.81%	3	46403	4.17%	4
IN	India	3563	3.31%	4	2493	3.38%	4	45556	4.09%	5
DE	Germany	3009	2.79%	6	2116	2.87%	6	16535	1.49%	15
ZA	**South Africa**	**709**	**0.66%**	**30**	**535**	**0.72%**	**29**	**12839**	**1.15%**	**19**
NG	**Nigeria**	**230**	**0.21%**	**52**	**189**	**0.26%**	**51**	**2397**	**0.22%**	**53**
KE	**Kenya**	**155**	**0.14%**	**67**	**120**	**0.16%**	**65**	**1995**	**0.18%**	**59**
GH	**Ghana**	**95**	**0.09%**	**84**	**83**	**0.11%**	**80**	**594**	**0.05%**	**105**
TZ	**Tanzania, United Republic of**	**89**	**0.08%**	**85**	**72**	**0.10%**	**86**	**681**	**0.06%**	**98**
EG	**Egypt**	**82**	**0.08%**	**88**	**65**	**0.09%**	**89**	**7730**	**0.69%**	**30**
AO	**Angola**	**60**	**0.06%**	**96**	**51**	**0.07%**	**95**	**335**	**0.03%**	**124**
UG	**Uganda**	**51**	**0.05%**	**101**	**41**	**0.06%**	**102**	**688**	**0.06%**	**96**
RW	**Rwanda**	**21**	**0.02%**	**137**	**18**	**0.02%**	**128**	**349**	**0.03%**	**122**

Here you can see statistics on the registered ASNs, announced ASNs and announced prefixes.

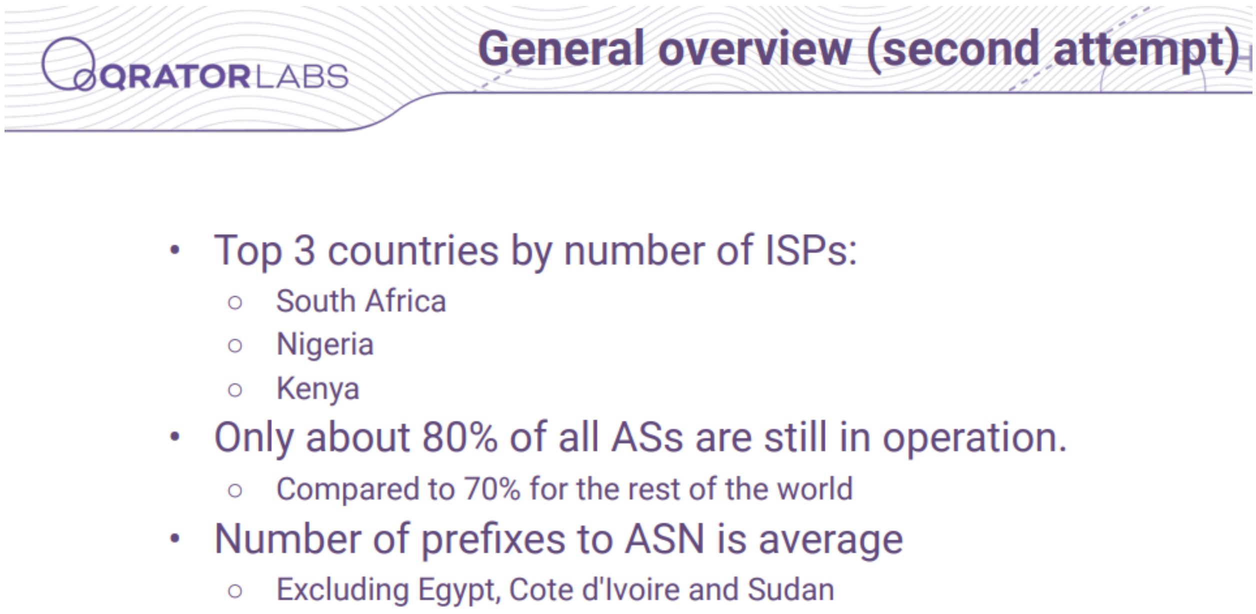
Looking at the results, we can find that South Africa, Nigeria and Kenya came out on top by a significant margin. It was already said at this conference what the reasons are: in these countries, there is a growing market, and over the past few years, there have been many new operators trying to provide their services in these countries.

QRATOR LABS

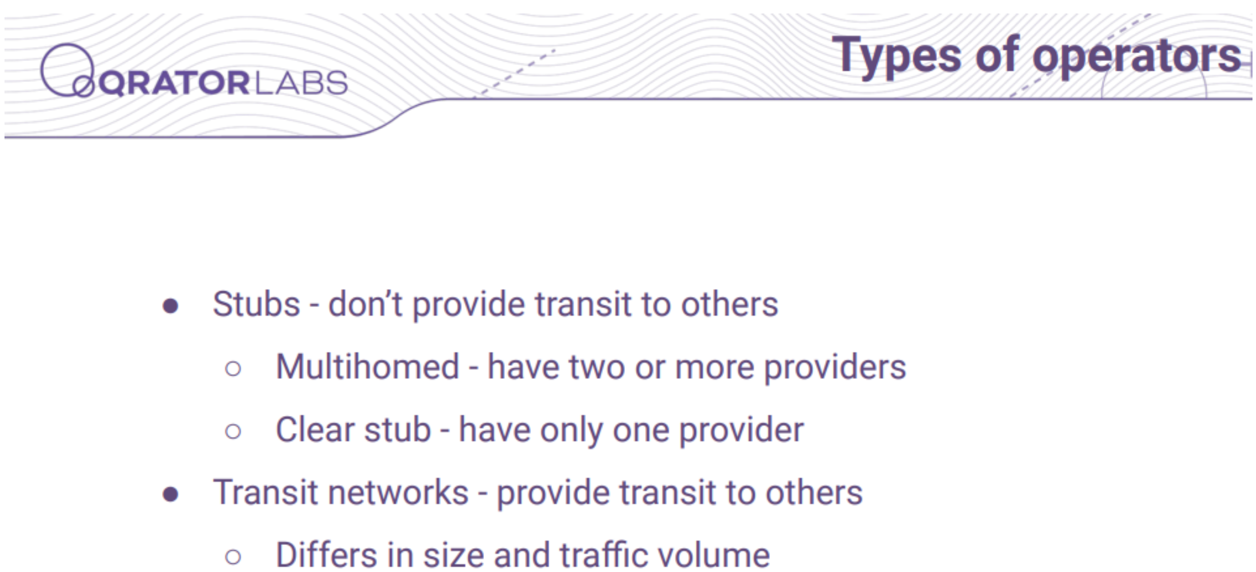
Too Much Information?

- ~54 countries to display
  - Differ from individual country reports
- Either aggregation or top displaying is needed

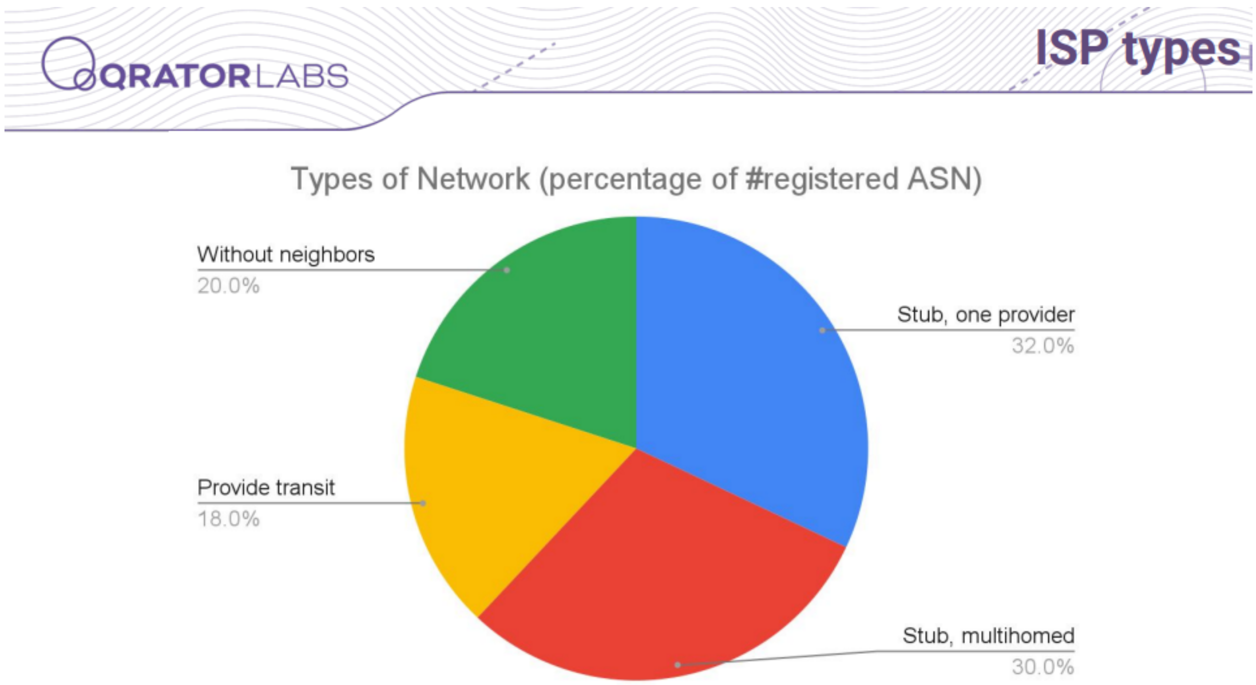
But there are 54 countries to display, so how do we decide which subset of the total data we want to show? So, for the rest of this presentation, we'll talk about countries that rank in the top or median places, emphasizing how a region ranks in this indicator.



Also, I want to highlight that the above top 3 countries have more than half of all ISPs in the region. So when something happens with these countries, it could affect the region and thus influence the whole continent.



We looked at the total number of ISPs, but ISPs can vary and play different roles. First, as an operator, you can create your own ASN to provide local services to your local customers/users, such as banks, universities, or any other organization. You have to buy a network prefix, announce it, and don't care how the network works. And there is another part, a specific role - the transit network, whose task is to connect these local operators with the rest of the world.



Let's take a look at the pie chart, with the help of which we will find out that the first type of operator is the most common. They occupy ¾ of all the active ISP's space. So the number of transit operators is relatively tiny, but they play a massive part in Internet health.

QRATOR LABS

Big fish

- Biggest Tier-1s - Cogent (AS174), Telia(AS1299), Level3(3356)
- Biggest Regional Providers - ?
    - Consumer cone analysis not working (Tier-1 will overtake it)
    - We will try to use flow analysis
- The border of the regions was taken from the African Union

Who are the most significant transit operators on the continent? Of course, we got to name some of the Tier-1s: Cogent with a considerable lead, then Telia and Level3. But we cannot look exclusively at the Tier-1s, some big Tier-2 operators interconnect the region from the inside, and they cannot be found by a consumer cone or a similar metric. So we need to design our own metric to highlight how they are critical to the region.

QRATOR LABS

Flow analysis

- Each country’s ISP has a default weight
    - Weight can be as a number of Prefixes/PTRs/clients/etc
    - **All country ISPs have equal weight** in our case
- The transit provider will get the extra weight of their customers
    - All weights in = All weights out
    - The client gives each provider the same part of its own weight
    - Similar to PageRank

So, to create a new metric, we will make two assumptions. First, we will consider all of the country's ASNs equal and give them a similar weight. And the second assumption is that the transit provider equally distributes all of his weight to all outgoing provider sessions. So everything is equal, and providers are identical, which is simple enough. And now, let's take a look at what result these assumptions give us.

Of course, we will see Seacom, which provides cable interconnection in Southern and East Africa. Liquid technologies, a participant at AfPIF (and the only company connected West to East by land) and West Indian Ocean Cable Company - WIOCC.

In the West, Mainone takes the lead with Dolphin Telecom.

A particularly interesting situation exists in the Northern and Central parts of Africa. Because Egypt and Cameroon are a big part of the Northern and Central regions, these countries' most significant transit operators automatically became the region's biggest transit operators.

Flow diversity

- About half of the countries have at least 1 ISP with more than 50% flow control.
- Most of them are countries with 10 or fewer ISPs.
- The most notable exceptions are:
  - Egypt - TE-AS(AS8452) (65 ASNs, ~52%)
  - Angola - ANGOLA-CABLES(AS37468) (51 ASNs, ~70%)
- A notable example of flow diversity:
  - Seychelles - most ISPs are directly connected to Tier-1s

What about other countries? Most African countries have 10 or fewer active ISPs. That is why you can always find one transit operator that will control more than half of the whole traffic for a given country. The most notable exceptions are Egypt and Angola with Angola Cables ISP.

On the other hand, there are Seychelles, whose ISPs are directly connected to the Tier-1s. And none of the Seychelles ISPs has more than 10% of the country's traffic under control.

Plan of the report

About measurements

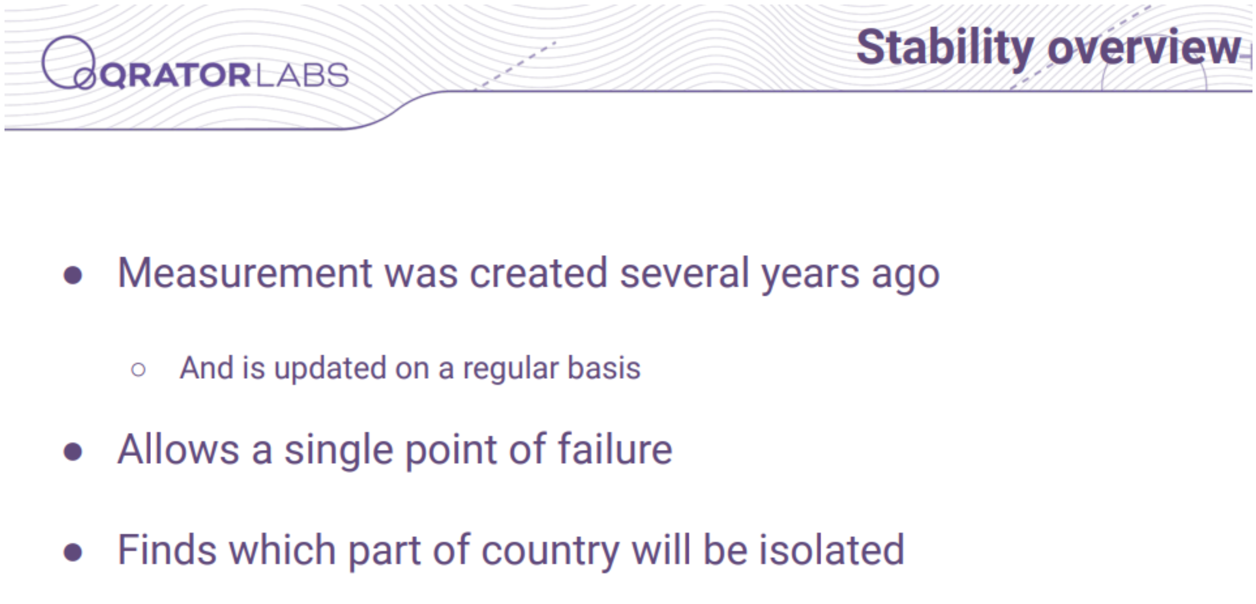
General overview

Stability overview

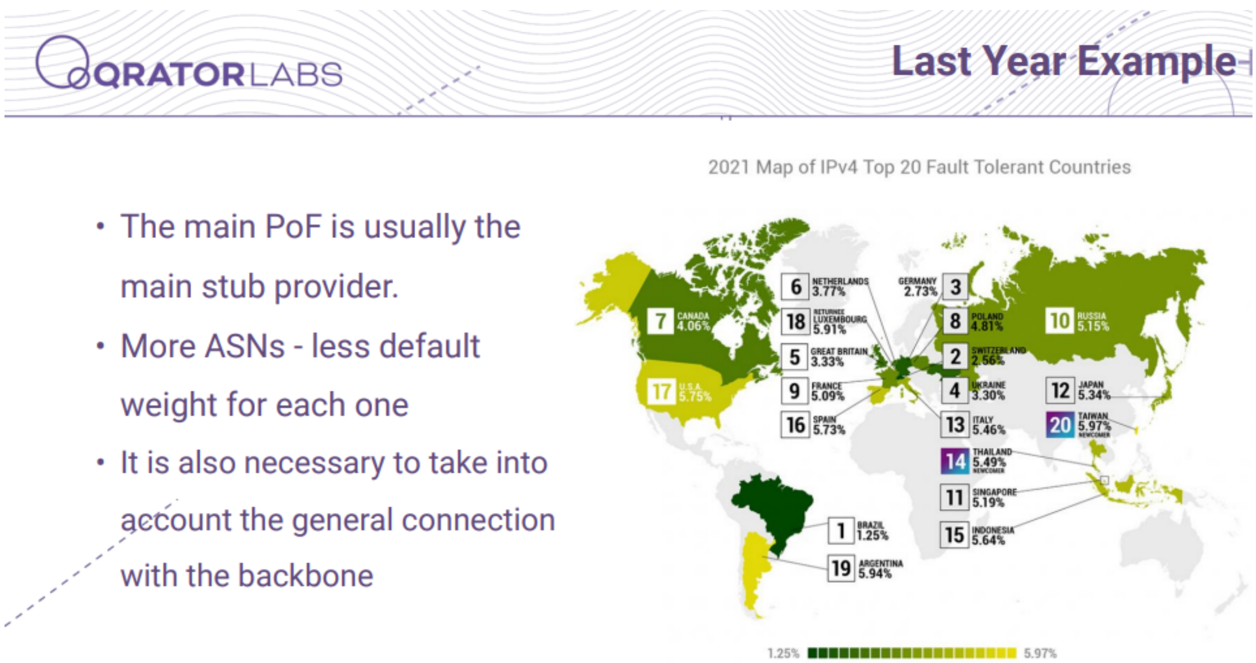
Prefix violation (Hijacking)

IPv6 adoption

So what will happen with TE-AS and Angola-Cables if they go offline? How stable will the region remain?



To explore this area, we created our own metric and modeled this situation precisely.



We've made some discoveries during several years of conducting reliability research.

iso	name	World_Place	Regional_Place	Critical ASN	#Depended ASNs	Critical %	Partial %
BR	Brazil	1		61832	127	1.54%	0.28%
DE	Germany	2		3320	53	2.49%	0.33%
RU	Russian Federation	12		12389	272	5.39%	0.67%
SC	**Seychelles**	**13**	**1**	**50673**	**2**	**5.41%**	**0.00%**
KE	**Kenya**	**33**	**2**	**33771**	**10**	**8.26%**	**1.65%**
MU	**Mauritius**	**48**	**3**	**33764**	**3**	**11.11%**	**7.41%**
ZA	**South Africa**	**61**	**7**	**37100**	**69**	**12.87%**	**2.43%**
NG	**Nigeria**	**76**	**9**	**37282**	**29**	**15.34%**	**1.59%**
RW	**Rwanda**	**83**	**11**	**16637**	**3**	**16.67%**	**0.00%**
EG	**Egypt**	**96**	**12**	**8452**	**13**	**20.00%**	**1.54%**
AO	**Angola**	**150**	**33**	**37468**	**20**	**39.22%**	**0.00%**

Reliability statistics, where we show a place in the global and regional rating, critical ASN and a percentage of intrastate resources that would be rendered offline in case of AS failure as the Critical %.

As expected, countries trying to create and grow corresponding local telecommunications markets are among the top, such as Seychelles, top-3 African markets we already mentioned and Mauritius.

And as for Egypt and Angola, such a high order of control of the country’s traffic could result in a considerable part of the region being cut off from the Internet (or, in this case, global transit) if TE-AS or Angola-Cables go offline.

QRATOR LABS

Who is a legitimate sender?

- IRR
    - Worked on AS_SET + route objects basis
    - Routes are usually filtered by prefix whitelist of created Customer Cone
    - Is needed for global connectivity
- ROA/RPKI
    - Worked as <Prefix, origin ASN> pair check
    - Is needed to prevent others from malicious activity
    - Has a side question - which maxLength to use?

When we talk about prefix violations and BGP hijacks, there are two types of legitimacy-stating objects that we must take into consideration: route objects and ROA objects.

QRATOR LABS

Validation Statuses

- Valid - <prefix, origin ASN> is covered by legitimate object
- Unknown - there is no legitimate object for a prefix
- Invalid - prefix belonged to another origin ASN

They can give you different validation statuses of the routes based on this information, and it is a common practice to drop invalid routes.

QRATOR LABS

Validation stats

What to measure - the percentage of prefixes?

	prefixes	route_valid	route_unknown	route_invalid	roa_valid	roa_unknown	roa_invalid
All countries	1118441	82.75%	8.54%	8.71%	35.06%	58.35%	**6.59%**
Africa	40535	91.87%	4.68%	3.45%	15.79%	75.50%	**8.71%**
Without ZA	27632	89.71%	6.24%	4.05%	14.52%	85.04%	0.43%

If we look at what is happening in the African region regarding the validity of objects, we can see that the number of ROA invalid routes is bigger than in the rest of the world. But if we take South Africa out of the equation, it will remain relatively low. How so?

QRATOR LABS

What are you trying to measure?

- Routes can be crafted
  - By BGP Optimisers or by similar tools
- Routes can be local
  - And accidently be leaked to BGP collector
- Routes can be filtered locally
  - And they will not be seen by other projects

Most hijacked routes stay local because of the different conditions: BGP optimizers, human errors, etc.

QRATORLABS

Validation stats [2]

Same metrics after filtering low visible routes

seen by at least 10 different ASNs

	prefixes	route_valid	route_unknown	route_invalid	roa_valid	roa_unknown	roa_invalid
All	965536	86.07%	6.53%	7.40%	38.32%	61.09%	**0.58%**
Africa	33532	91.27%	5.33%	3.40%	18.57%	81.09%	**0.34%**
Without ZA	26813	90.34%	6.03%	3.63%	14.63%	84.99%	0.38%

If we filter these routes out, we will receive a much brighter picture and this type of analytics we will count on and see that currently, around 20% of routes are signed with ROA objects. It is good enough, but still not as high as in the rest of the world.

QRATORLABS

Problems with prefix validation

- Most hijackers are not real hijackers
- Data scrubbing required
- Real analysis needs AS_PATH
  - The problem was highlighted on ENOG a few years ago (link)

Link from the slide.

There are several problems around the BGP hijacking - therefore, you need to scrub the data to have accurate results.

QRATOR LABS

IPv6 average adoption

only ~35% ASNs announced IPv6 prefixes

(compared to IPv4)

And if we talk about the IPv6 adoption rate, only ⅓ of all the ISPs are currently trying to provide IPv6 services.

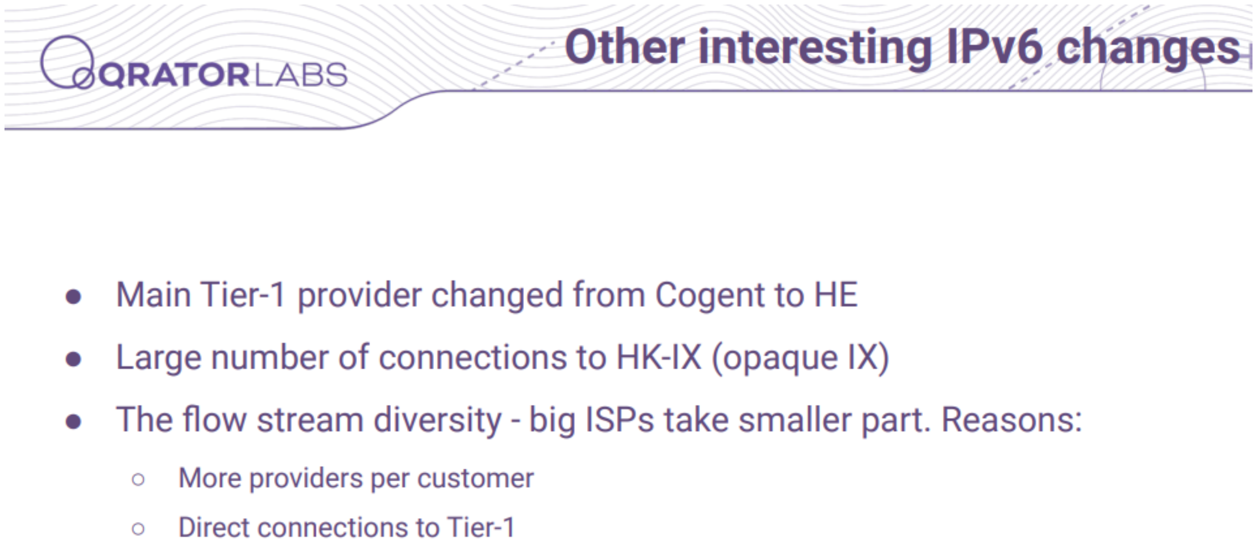
QRATOR LABS

IPv6 adoption stats

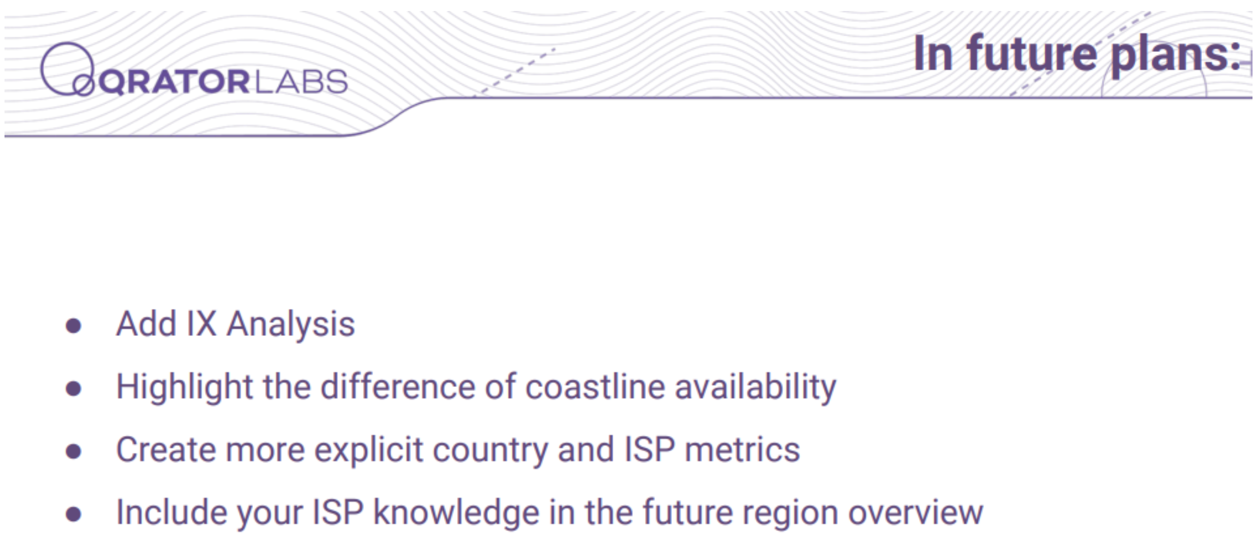
		# Registered ASNs			# Announced ASNs			
iso	name	Value	Percentage	Place	Value	Percentage	Place	Rate v6/v4
BR	Brazil	8946	8.30%	2	6227	21.02%	1	76.40%
US	United States	29499	27.39%	1	3921	13.24%	2	21.89%
DE	Germany	3009	2.79%	6	1429	4.82%	3	67.53%
ZA	South Africa	709	0.66%	30	226	0.76%	24	42.24%
NG	Nigeria	230	0.21%	52	39	0.13%	62	20.63%
KE	Kenya	155	0.14%	67	34	0.11%	70	28.33%
TZ	Tanzania, United Republic of	89	0.08%	85	31	0.10%	72	43.06%
SC	Seychelles	55	0.05%	100	18	0.06%	87	48.65%
AO	Angola	60	0.06%	96	13	0.04%	95	25.49%
MU	Mauritius	47	0.04%	106	12	0.04%	96	44.44%
GH	Ghana	95	0.09%	84	12	0.04%	97	14.46%
EG	Egypt	82	0.08%	88	11	0.04%	101	16.92%
MA	Morocco	24	0.02%	127	10	0.03%	106	50.00%
UG	Uganda	51	0.05%	101	10	0.03%	108	24.39%
RW	Rwanda	21	0.02%	137	3	0.01%	160	16.67%

Statistics on the IPv6 adoption in the region and the world's leading countries.

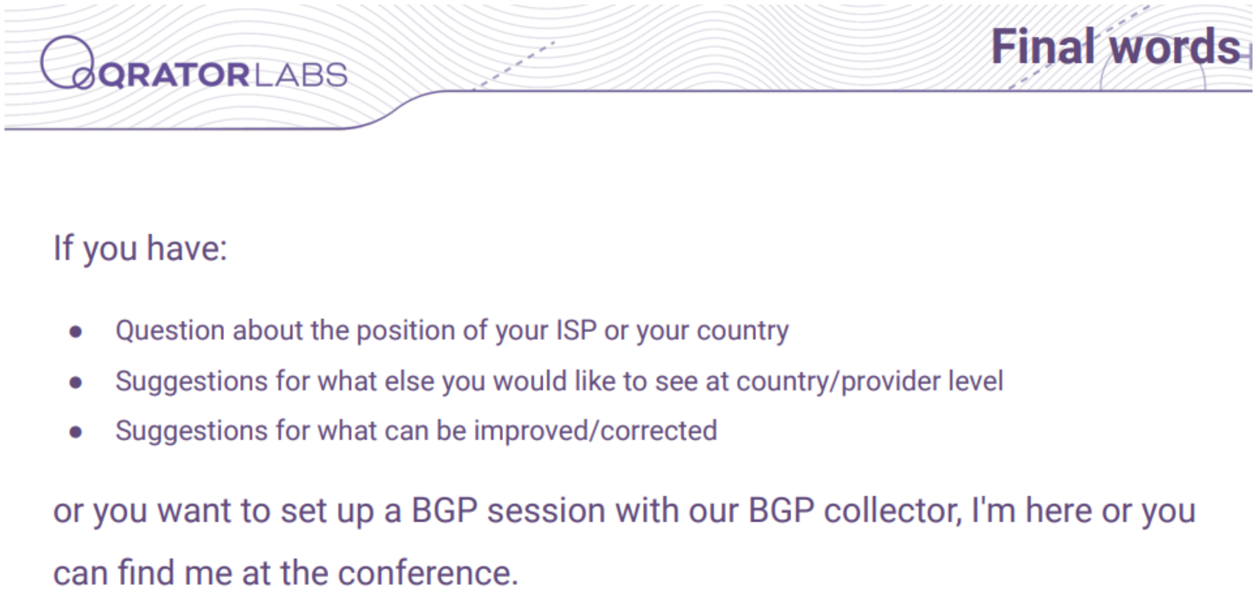
Of course, among the top players are countries that we expect to be there. Here you can look at some of the results for these countries.



And if we highlight the main differences in IPv6 - the leading Tier-1 provider changes from Cogent to Hurricane Electric because it tries to be present on every IX and beyond those. Also, let's say you're trying to become a big player in the IPv6 world. In this case, you should support as many providers and peers as possible. Because of this diversification, other big players have less control over the total region flow.



As a final remark, I should say that we will try adding different types of analysis to the data to highlight local features in the future. One of them is the massive presence of IXPs, and the difference created by the coastline and landlocked countries. And, of course, we want to include your ISP knowledge of the region in our future region overviews.



If you have any questions about what is going on, what's your position if not seen in the presented charts, or you have any suggestions on what could be improved and what you want us to measure, you can find me here or write us an email at radar@qrator.net

Thank you!