

# Global R&E Routing Table Update

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UNIVERSITY OF OREGON



# Motivation

- 1998: No one was publishing any Internet routing table analysis
  - Only CIDR-Report reporting on top 20 contributors to routing table, and top 20 bad aggregators
- 1999: Started weekly report looking at Global Internet Routing Table
  - Routing table size
  - CIDR-Report style reporting on a per-RIR basis
- 2019: Started recording Global R&E Routing Table
  - Feeds from University of Guam and DrukREN (Bhutan)

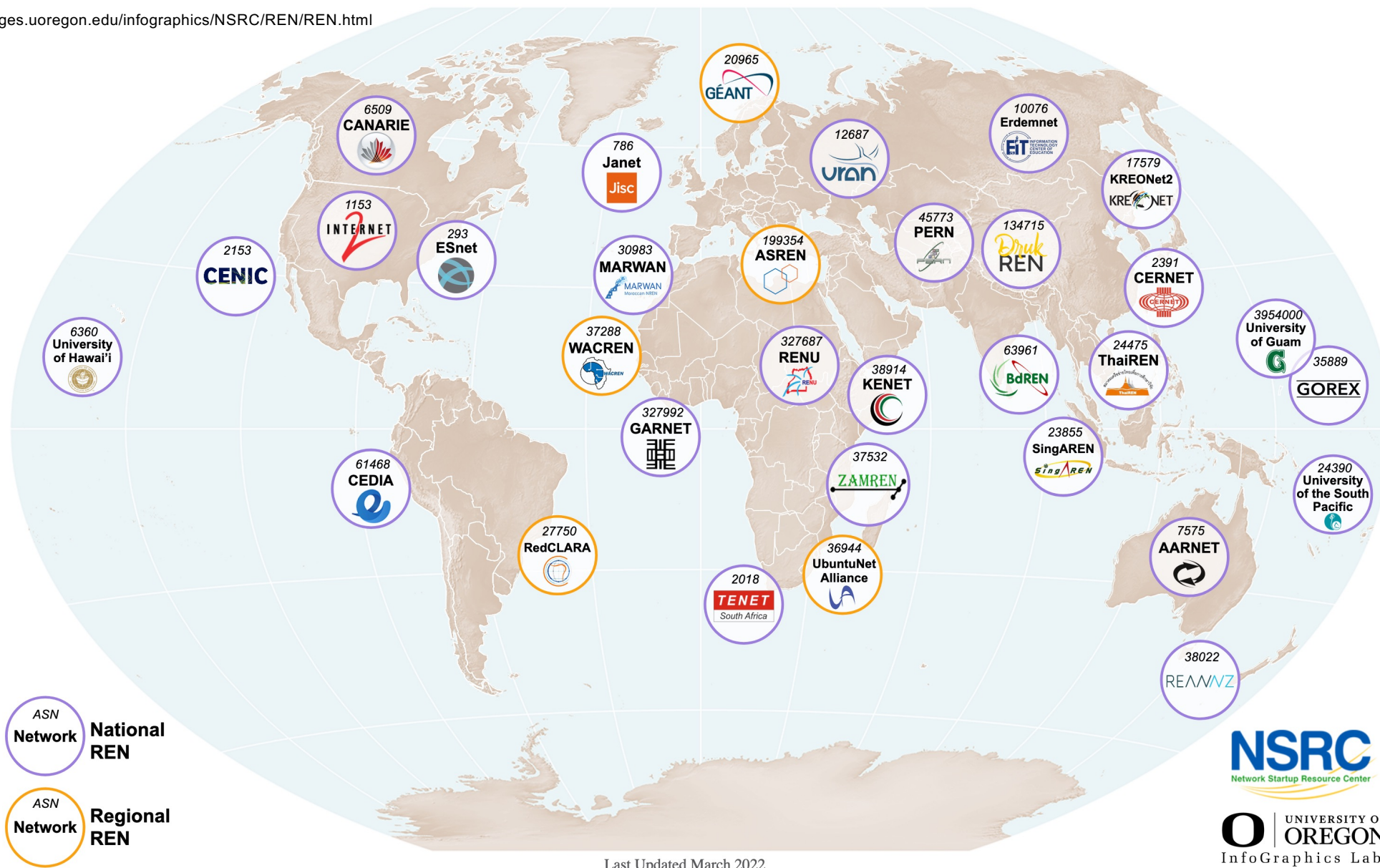
# Goals

- Part of NSRC's NSF INRC engagement:
  - Assessing aggregation
  - Finding local and regional misconfigurations
  - Discovering problems with announcements
  - Encouraging RPKI deployment
  - Helping R&E network operators improve routability
  - Supporting global awareness and compliance with MANRS initiative
    - <https://manrs.org>



# Technical

- NSRC collector hosted at University of Oregon
  - Using FRR (<http://frrouting.org>)
  - Technical configuration:
    - <https://bgp.nsrc.org/REN/tech.html>
- R&E network operator sets up EBGP Multihop peering with NSRC collector
  - Sends their view of the global R&E routing table
  - NSRC collector sends nothing – it is just a collector
- Analysis scripts runs daily and reports interesting data:
  - <https://bgp.nsrc.org/REN/index.html>



Last Updated March 2022

Site	Prefixes	ASNs	Valid	Invalid	NotFound
AARNET-Seattle	17438	2610	3636	16	13786
ASREN	13112	2065	3368	0	9744
BDREN	18472	2752	4058	24	14390
CANARIE	18779	2762	3846	44	14889
CEDIA	23529	2714	8979	175	14375
CENIC	21964	2757	7272	16	14676
CERNET	16902	2611	3806	16	13080
DrukREN	18390	2729	3977	23	14390
ESnet	19981	2994	4088	14	15879
Erdemnet	18885	2787	4131	123	14631
GEANT	18728	2763	4030	18	14680
Internet2	22004	2740	7136	45	14823
Janet	18129	2655	3916	0	14213
KENET	16972	2523	3974	4	12994
KREONet2	20025	2768	5196	47	14782
MARWAN	13553	2066	3366	0	10187
PERN	18269	2744	3866	18	14385
REANNZ	18402	2742	3828	0	14574
RedCLARA	18174	2706	3800	36	14338
SingAREN	18290	2744	3871	19	14400
TENET	16023	2273	2769	17	13237
URAN	18444	2686	3937	1	14506
UbuntuNet	17483	2698	3715	0	13768
UniGuam	19987	2297	6930	99	12944
UniHawaii	23033	2763	7568	95	15370
WACREN	18383	2735	4017	30	14336
<i>GOREX</i>	<i>956</i>	<i>167</i>	<i>127</i>	<i>5</i>	<i>824</i>
<i>AARNET</i>	<i>892907</i>	<i>73152</i>	<i>327853</i>	<i>3092</i>	<i>561962</i>
<i>RENU</i>	<i>915504</i>	<i>73208</i>	<i>343053</i>	<i>2819</i>	<i>569632</i>
<i>USP</i>	<i>892862</i>	<i>73215</i>	<i>327814</i>	<i>3102</i>	<i>561946</i>

## IPv4 R&E Table Size Summary

31<sup>st</sup> May 2022



# R&E View IPv4 differences

## Internet 2

ASN	No of nets	/20 equiv	MaxAgg	Description
16509	2707	4558	1207	AMAZON-02, US
14618	611	3990	467	AMAZON-AES, US
2907	578	2140	456	SINET-AS Research Organization of Infor
7497	432	182	24	CSTNET-AS-AP Computer Network Informati
2018	375	319	74	TENET-1, ZA

## DrukREN

ASN	No of nets	/20 equiv	MaxAgg	Description
2907	571	2140	454	SINET-AS Research Organization of Infor
7497	432	182	24	CSTNET-AS-AP Computer Network Informati
2018	376	319	74	TENET-1, ZA
680	284	1967	251	DFN Verein zur Foerderung eines Deutsch
36914	215	82	3	KENET-AS, KE

## ASREN

ASN	No of nets	/20 equiv	MaxAgg	Description
2907	578	2140	456	SINET-AS Research Organization of Infor
7497	427	177	19	CSTNET-AS-AP Computer Network Informati
680	284	1967	251	DFN Verein zur Foerderung eines Deutsch
36914	215	82	3	KENET-AS, KE
376	202	178	151	RISQ-AS, CA

## CEDIA

ASN	No of nets	/20 equiv	MaxAgg	Description
396982	1931	2112	345	GOOGLE-CLOUD-PLATFORM, US
16509	1707	1602	668	AMAZON-02, US
15169	737	3278	67	GOOGLE, US
2907	619	2140	456	SINET-AS Research Organization of Infor
14618	610	3990	466	AMAZON-AES, US

## TENET

ASN	No of nets	/20 equiv	MaxAgg	Description
2907	571	2140	454	SINET-AS Research Organization of Infor
7497	432	182	24	CSTNET-AS-AP Computer Network Informati
2018	376	319	74	TENET-1, ZA
36914	215	82	3	KENET-AS, KE
668	210	702	178	DNIC-AS-00668, US

Site	Prefixes	ASNs	Valid	Invalid	NotFound
AARNET-Seattle	6332	5128	851	111	5370
ASREN	5568	4903	715	0	4853
BDREN	5761	5029	600	77	5084
CEDIA	7824	5132	2282	121	5421
CENIC	6434	5160	877	113	5444
CERNET	1589	830	789	32	768
DrukREN	6369	5158	826	110	5433
ESnet	6426	5202	718	86	5622
Erdemnet	6411	5148	868	112	5431
GEANT	6392	5168	916	6	5470
Internet2	7310	5160	1729	116	5465
Janet	6198	5150	913	0	5285
KENET	6246	5092	852	5	5389
KREONet2	9194	5326	2615	126	6453
MARWAN	5662	4904	713	0	4949
PERN	6406	5146	866	112	5428
REANNZ	6324	5155	882	0	5442
RedCLARA	6408	5130	876	114	5418
SingAREN	6445	5162	884	117	5444
TENET	7034	4971	1590	118	5326
URAN	6386	5167	916	0	5470
UbuntuNet	6222	5101	849	5	5368
UniGuam	1379	283	803	131	445
UniHawaii	25469	8705	10373	505	14591
<i>GOREX</i>	<i>126</i>	<i>71</i>	<i>46</i>	<i>4</i>	<i>76</i>
<i>AARNET</i>	<i>154453</i>	<i>28807</i>	<i>62709</i>	<i>1043</i>	<i>90701</i>
<i>CANARIE</i>	<i>148432</i>	<i>28702</i>	<i>62474</i>	<i>170</i>	<i>85788</i>
<i>RENU</i>	<i>151917</i>	<i>28801</i>	<i>63725</i>	<i>1958</i>	<i>86234</i>
<i>USP</i>	<i>153336</i>	<i>28760</i>	<i>62611</i>	<i>24</i>	<i>90701</i>
<i>WACREN</i>	<i>142865</i>	<i>28166</i>	<i>60024</i>	<i>150</i>	<i>82691</i>
<i>ZAMREN</i>	<i>141443</i>	<i>28164</i>	<i>58000</i>	<i>222</i>	<i>83221</i>

## IPv6 R&E Table Size Summary

31<sup>st</sup> May 2022





# R&E View IPv6 differences

## Internet 2

ASN	No of Nets	Description
16509	702	AMAZON-02, US
7497	160	CSTNET-AS-AP Computer Network Information Center, CN
14618	143	AMAZON-AES, US
55824	93	NKN-CORE-NW NKN Core Network, IN
45773	70	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa

## DrukREN

ASN	No of Nets	Description
7497	155	CSTNET-AS-AP Computer Network Information Center, CN
55824	94	NKN-CORE-NW NKN Core Network, IN
45773	70	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa
133111	64	CNT-NORTHCHINA CERNET New Technology Co., Ltd, CN
4758	62	NICNET-VSNL-BOARDER-AP National Informatics Centre, IN

## ASREN

ASN	No of Nets	Description
55824	78	NKN-CORE-NW NKN Core Network, IN
45773	70	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa
4758	59	NICNET-VSNL-BOARDER-AP National Informatics Centre, IN
134715	47	DRUKREN-MOIC-AS Ministry of Information & Communications Thi
61468	33	CEDIA, EC

## CEDIA

ASN	No of Nets	Description
36492	713	GOOGLEWIFI, US
16509	428	AMAZON-02, US
7497	160	CSTNET-AS-AP Computer Network Information Center, CN
14618	142	AMAZON-AES, US
55824	93	NKN-CORE-NW NKN Core Network, IN

## TENET

ASN	No of Nets	Description
16509	702	AMAZON-02, US
7497	155	CSTNET-AS-AP Computer Network Information Center, CN
14618	143	AMAZON-AES, US
55824	94	NKN-CORE-NW NKN Core Network, IN
45773	70	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa

# Analysis Summaries

- Data in the following graphics taken primarily from DrukREN
  - R&E feed dating from 28<sup>th</sup> April 2019
  - Most informative to show trends
- Data in other summaries taken from all the feeds
  - Looking for unusual features of the Global R&E table

# IPv4 Routing Report 31<sup>st</sup> May 2022 (DrukREN)

BGP routing table entries examined:	18390
Prefixes after maximum aggregation (per Origin AS):	10491
Deaggregation factor:	1.75
Unique aggregates announced (without unneeded subnets):	11665
Number of IPv4 prefixes with a valid ROA:	3977
Number of IPv4 prefixes with an invalid ROA:	23
Number of IPv4 prefixes with no ROA:	14390
Total ASes present in the Internet Routing Table:	2729
Prefixes per ASN:	6.74
Origin-only ASes present in the Internet Routing Table:	2349
Origin ASes announcing only one prefix:	1096
Transit ASes present in the Internet Routing Table:	380
Transit-only ASes present in the Internet Routing Table:	58
Average AS path length visible in the Internet Routing Table:	7.1
Max AS path length visible:	18
Max AS path prepend of ASN ( 1149)	11
Prefixes from unregistered ASNs in the Routing Table:	7
Number of instances of unregistered ASNs:	7
Special use prefixes present in the Routing Table:	1
Prefixes being announced from unallocated address space:	2
Number of addresses announced to Internet:	205065728
Equivalent to 12 /8s, 57 /16s and 14 /24s	
Total number of prefixes smaller than registry allocations:	1951

## Global IPv4 per AS prefix count summary (DrukREN)

ASN	No of nets /20	equiv	Max	Agg	Description
2907	571	2140	454	SINET-AS	Research Organization of Infor
7497	432	182	24	CSTNET-AS-AP	Computer Network Informati
2018	376	319	74	TENET-1,	ZA
680	284	1967	251	DFN Verein zur Foerderung eines Deutsch	
36914	215	82	3	KENET-AS,	KE
668	210	702	178	DNIC-AS-00668,	US
376	202	178	151	RISQ-AS,	CA
5786	200	16	1	UPRENET,	PR
1237	187	74	135	KREONET-AS-KR	KISTI, KR
786	186	1774	183	JANET Jisc Services Limited,	GB
7575	177	330	123	AARNET-AS-AP	Australian Academic and Re
58647	175	18	2	KAGAWAU-AS	Kagawa University, JP
4758	159	16	1	NICNET-VSNL-BOARDER-AP	National Informa
1916	156	208	45	Rede Nacional de Ensino e Pesquisa,	BR
2152	152	507	90	CSUNET-NW,	US
28391	152	10	66	Universidad Juarez Autonoma de Tabasco,	
8895	138	24	4	ISU Internet Services Unit	ISU, SA
55824	137	19	29	NKN-CORE-NW	NKN Core Network, IN
18558	131	18	4	NETBLK-RCOEK,	US
4538	128	4192	73	ERX-CERNET-BKB	China Education and Rese



# Non-routable addresses

## List of Unassigned addresses

Unassigned Network	ASN Information	AS Name
192.31.196.0/24	Origin: 112	ROOTSERV
	Transit: 1103	SURFNET-NL SURFnet, The Netherlands, NL
192.88.99.0/24	Origin: 1103	SURFNET-NL SURFnet, The Netherlands, NL
	Transit: 23855	SINGAREN-GIX-AS-AP Singapore Advanced Re

- Some notes about these:
  - 192.31.196.0/24 is listed as “IANA Reserved”
  - 192.88.99.0/24 is listed as “IANA Special Use”
    - It is the **deprecated** 6to4 relay address (RFC7526/BCP196 – May 2015)
    - And: please do NOT use tunnels for IPv6!!
- Generally considered unsafe to transit such address space

# Non-routable ASNs

## List of Unregistered Origin ASNs

Bad AS	Designation	Net Originated	Transit AS	Transit AS Name
65200	PRIVATE	43.224.124.0/22	132124	ICTA-LK Information and Comm
65200	PRIVATE	103.11.32.0/22	132124	ICTA-LK Information and Comm
22063	UNALLOCATED	153.10.0.0/16	2152	CSUNET-NW, US
22226	UNALLOCATED	156.1.0.0/16	2152	CSUNET-NW, US
19658	UNALLOCATED	199.27.241.0/24	11096	FLORIDANET, US
395514	UNALLOCATED	205.213.88.0/24	2381	WISCNET1-AS, US
394607	UNALLOCATED	216.100.93.0/24	23024	OCDE, US

- Some notes about these:
  - AS 22063, AS 22226, AS 19658, AS 394607 and AS 395514 are not registered
  - AS 65200 is a Private ASN – must not be routed

```

I*> 43.224.124.0/22          134715 9885 38229 132124 65200
I*> 103.11.32.0/22         134715 9885 38229 132124 65200
    
```

Information and  
Communication  
Technology Agency  
of Sri Lanka

- Why are the transit ASes providing transit to unregistered Internet resources?



# Deprecated AS Set

- Use of BGP AS Set is not recommended
  - RFC6472/BCP172 (December 2011)
  - Still some in the BGP table:

## Prefixes using Deprecated AS\_SET

Net Originated	AS Path
130.184.0.0/16	134715 9885 23855 7660 22388 11537 40581 10508 {10508}
198.202.64.0/18	134715 9885 23855 7660 22388 2153 195 {195}
198.202.96.0/19	134715 9885 23855 7660 22388 2153 195 {195}

- Looks like an automated (mis)configuration as the AS\_SET above is meaningless

## Number of IPv4 prefixes announced by prefix length

/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:1
/9:1	/10:2	/11:1	/12:12	/13:19	/14:37	/15:125	/16:2142
/17:370	/18:438	/19:620	/20:878	/21:925	/22:1357	/23:1410	/24:10042
/25:87	/26:56	/27:76	/28:35	/29:41	/30:28	/31:1	/32:194

31<sup>st</sup> May 2019 ↑

31<sup>st</sup> May 2022 ↓

/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:0
/9:1	/10:2	/11:1	/12:10	/13:18	/14:34	/15:122	/16:2009
/17:401	/18:437	/19:570	/20:888	/21:860	/22:1388	/23:1533	/24:10116
/25:0	/26:0	/27:0	/28:0	/29:0	/30:0	/31:0	/32:0



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# RPKI Invalids

- DrukREN sees 27 prefixes with invalid ROAs
  - If they did Route Origin Validation these would be dropped
  - Are they hijacks?
  - Or “fat finger”?
  - Or “forgetfulness”?

Network	Path
I*> 14.139.253.0/24	134715 9885 55824
I*> 43.224.124.0/22	134715 9885 38229 132124 65200
I*> 45.182.117.0/24	134715 9885 23855 23864 11537 61468 27947
I*> 103.11.32.0/22	134715 9885 38229 132124 65200
I*> 103.127.161.0/24	134715 9885 55824
I*> 140.109.102.0/24	134715 9885 23855 7660 24167
I*> 140.115.32.0/24	134715 9885 23855 24490 24167 7539 1659
I*> 140.115.38.0/24	134715 9885 23855 24490 24167 7539 1659
I*> 149.149.248.0/22	134715 9885 23855 23864 11537 10490 33600
I*> 163.253.0.0/24	134715 9885 23855 23864 11537
I*> 163.253.3.0/24	134715 9885 23855 23864 11537
I*> 163.253.12.0/23	134715 9885 23855 23864 11537
I*> 163.253.14.0/23	134715 9885 23855 23864 11537
I*> 164.100.52.0/24	134715 9885 4758 55824
I*> 164.100.224.0/23	134715 9885 4758 55824
I*> 164.100.226.0/23	134715 9885 4758 55824
I*> 170.210.216.0/22	134715 9885 23855 23864 11537 27750 3597 4270 263204
I*> 190.114.220.0/24	134715 9885 23855 23864 11537 27750 3597 4270 27883
I*> 200.69.124.0/24	134715 9885 23855 23864 11537 27750 27817 21578
I*> 201.245.186.0/24	134715 9885 23855 23864 11537 27750 27817 21578
I*> 202.169.168.0/22	134715 9885 23855 7660 24167
I*> 202.249.24.0/24	134715 9885 23855 134148 35889 141682 2500 4717
I*> 202.249.25.0/24	134715 9885 23855 134148 35889 141682 2500 4717
I*> 210.48.157.0/24	134715 9885 23855 24514 4788 18206 17971 18206
I*> 220.247.225.0/24	134715 9885 38229 9329 132124



# ROAs vs RPKI Invalids

Prefix	Prefix Length	Origin-AS	Network	Path
14.139.252.0	23 - 23	55824	I*> 14.139.253.0/24	134715 9885 55824
43.224.124.0	22 - 22	132124	I*> 43.224.124.0/22	134715 9885 38229 132124 65200
45.182.117.0	24 - 24	269848	I*> 45.182.117.0/24	134715 9885 23855 23864 11537 61468 27947
103.11.32.0	22 - 22	132124	I*> 103.11.32.0/22	134715 9885 38229 132124 65200
103.127.160.0	23 - 24	138247	I*> 103.127.161.0/24	134715 9885 55824
140.109.0.0	16 - 16	9264	I*> 140.109.102.0/24	134715 9885 23855 7660 24167
140.115.0.0	16 - 16	18420	I*> 140.115.32.0/24	134715 9885 23855 24490 24167 7539 1659
140.115.0.0	16 - 16	18420	I*> 140.115.38.0/24	134715 9885 23855 24490 24167 7539 1659
149.149.0.0	16 - 29	19331	I*> 149.149.248.0/22	134715 9885 23855 23864 11537 10490 33600
163.253.0.0	16 - 16	11537	I*> 163.253.0.0/24	134715 9885 23855 23864 11537
163.253.0.0	16 - 16	11537	I*> 163.253.3.0/24	134715 9885 23855 23864 11537
163.253.12.0	24 - 24	11537	I*> 163.253.12.0/23	134715 9885 23855 23864 11537
163.253.14.0	24 - 24	11537	I*> 163.253.14.0/23	134715 9885 23855 23864 11537
164.100.0.0	18 - 24	4758	I*> 164.100.52.0/24	134715 9885 4758 55824
164.100.128.0	17 - 23	4758	I*> 164.100.224.0/23	134715 9885 4758 55824
164.100.128.0	17 - 23	4758	I*> 164.100.226.0/23	134715 9885 4758 55824
170.210.0.0	16 - 24	4270	I*> 170.210.216.0/22	134715 9885 23855 23864 11537 27750 3597 4270 263204
190.114.192.0	19 - 20	27883	I*> 190.114.220.0/24	134715 9885 23855 23864 11537 27750 3597 4270 27883
200.69.112.0	20 - 24	19429	I*> 200.69.124.0/24	134715 9885 23855 23864 11537 27750 27817 21578
201.245.0.0	16 - 24	19429	I*> 201.245.186.0/24	134715 9885 23855 23864 11537 27750 27817 21578
202.169.160.0	20 - 20	9264	I*> 202.169.168.0/22	134715 9885 23855 7660 24167
202.249.0.0	17 - 18	2500	I*> 202.249.24.0/24	134715 9885 23855 134148 35889 141682 2500 4717
202.249.0.0	17 - 18	2500	I*> 202.249.25.0/24	134715 9885 23855 134148 35889 141682 2500 4717
210.48.144.0	20 - 24	17971	I*> 210.48.157.0/24	134715 9885 23855 24514 4788 18206 17971 18206
220.247.192.0	18 - 24	9329	I*> 220.247.225.0/24	134715 9885 38229 9329 132124

# What about IPv6 ?

Table Size	6369
Total number of ASNs	5158
Total number of Origin ASNs	5121
Average AS Path length	6
Longest AS Path	14
Number of /32s	4554
Number of /48s	1197
Number of prefixes >/48	0 ← Filtering 😊
Number of prefixes >/32 and </48	535
Number of prefixes >/16 and </32	83



## Global IPv6 per AS prefix count summary (DrukREN)

ASN	No of Nets	Description
7497	155	CSTNET-AS-AP Computer Network Information Center, CN
55824	94	NKN-CORE-NW NKN Core Network, IN
45773	70	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa
133111	64	CNT-NORTHCHINA CERNET New Technology Co., Ltd, CN
4758	62	NICNET-VSNL-BOARDER-AP National Informatics Centre, IN
37963	60	ALIBABA-CN-NET Hangzhou Alibaba Advertising Co.,Ltd., CN
45090	37	TENCENT-NET-AP Shenzhen Tencent Computer Systems Company Lim
61468	33	CEDIA, EC
327687	25	RENU, UG
1916	17	Rede Nacional de Ensino e Pesquisa, BR
46047	16	POLSRI-AS-ID Politeknik Negeri Sriwijaya, ID
2018	15	TENET-1, ZA
31764	14	OAKLAND-USD-NET, US
4608	13	APNIC-SERVICES Asia Pacific Network Information Centre, AU
24151	13	CNNIC-CRITICAL-AP China Internet Network Infomation Center,
3477	12	NOAA-NWAVE, US
559	11	SWITCH Peering requests: peering@switch.ch, CH
680	11	DFN Verein zur Foerderung eines Deutschen Forschungsnetzes e
38365	11	BAIDU Beijing Baidu Netcom Science and Technology Co., Ltd.,
47065	10	PEERING-RESEARCH-TESTBED-USC-UFGM-AS47065, US

Mistake?  
They do not  
appear in  
IPv4 table



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AfriNIC APNIC ARIN LACNIC RIPE NCC



# Non-routable ASNs

## List of Unregistered Origin ASNs

Bad AS	Designation	Net Originated	Transit AS	Transit AS Name
65001	PRIVATE	2001:480:1c::/48	668	DNIC-AS-00668, US

- This one is interesting! Look at the path:

Network	Next Hop	Metric	LocPrf	Weight	Path
N*> 2001:480:1c::/48	2403:580::14:3	0		0	134715 9885 23855 7660 22388 668 65001 768 ?

- Not sure what is intended here... 🤔

# Deprecated AS Set

- Use of BGP AS Set is not recommended
  - RFC6472/BCP172 (December 2011)
  - Still some in the BGP table:

## Prefixes using Deprecated AS\_SET

Net Originated	AS Path
2001:410::/32	134715 9885 23855 2603 6509 {271,7860,8111,10972,53904}
2001:510::/32	134715 9885 23855 2603 6509 376 {36786}
2607:f390::/32	134715 9885 23855 7660 22388 11537 32440 {2055,17244}
2607:f558::/32	134715 9885 23855 7660 22388 11537 33189 {11602,11607,11736,22215,23122,26498}
2a0a:bcc0::/29	134715 9885 23855 2603 1653 41001 {64600,65001,65002,65501,65502}

- Unclear what the last entry is trying to achieve (ASNs in the AS\_SET are private)

## Number of IPv6 prefixes announced by prefix length

/16:0	/17:0	/18:0	/19:0	/20:1	/21:2	/22:0	/23:0
/24:1	/25:0	/26:1	/27:1	/28:6	/29:37	/30:7	/31:0
<b>/32:429</b>	/33:31	/34:15	/35:19	/36:34	/37:8	/38:12	/39:2
/40:113	/41:6	/42:4	/43:1	/44:92	/45:21	/46:4	/47:13
<b>/48:1174</b>	/49 → /128: 45 prefixes						

31<sup>st</sup> May 2019 ↑

31<sup>st</sup> May 2022 ↓

/16:0	/17:0	/18:0	/19:0	/20:2	/21:1	/22:2	/23:0
/24:2	/25:0	/26:1	/27:1	/28:6	/29:52	/30:13	/31:3
<b>/32:4554</b>	/33:44	/34:10	/35:27	/36:69	/37:15	/38:13	/39:1
/40:156	/41:10	/42:10	/43:2	/44:139	/45:18	/46:8	/47:13
<b>/48:1197</b>	/49 → /128: ZERO						



# RPKI Invalids

- DrukREN sees 114 prefixes with invalid ROAs
  - If they did Route Origin Validation these would be dropped
  - Are they hijacks?
  - Or “fat finger”?
  - Or “forgetfulness”?

Network	Path
I*> 2001:288:5001::/48	134715 9885 23855 7660 24167 7539 1659 e
I*> 2001:288:500b::/48	134715 9885 23855 7660 24167 7539 1659 e
I*> 2001:388:cf85::/48	134715 9885 23855 7575 i
I*> 2001:e30:1111::/48	134715 9885 55824 2697 i
I*> 2001:4408:1180::/44	134715 9885 55824 4758 ?
I*> 2001:4408:5d00::/44	134715 9885 55824 i
I*> 2001:4408:6200::/48	134715 9885 55824 4758 ?
I*> 2001:4408:6220::/48	134715 9885 55824 4758 ?
I*> 2001:48a8:68f7::/48	134715 9885 23855 23864 11537 237 231 229 i
I*> 2001:48a8:68fe::/48	134715 9885 23855 23864 11537 237 i
I*> 2400:a980::/32	134715 9885 23855 24490 24489 23911 23910 133111 i
I*> 2400:a980::/40	134715 9885 23855 24490 24489 23911 23910 133111 i
I*> 2400:a980:bf::/48	134715 9885 23855 24490 24489 23911 23910 133111 i
I*> 2400:a980:c1::/48	134715 9885 23855 24490 24489 23911 23910 133111 134169 i
<snip>	
I*> 2400:a980:90ff::/48	134715 9885 23855 24490 24489 23911 23910 133111 i
I*> 2405:8a00:bb::/48	134715 9885 55824 ?
I*> 2405:8a00:217e::/48	134715 9885 55824 ?
I*> 2405:8a00:401f::/48	134715 9885 55824 I
<snip>	
I*> 2407:9a00:1::/48	134715 9885 55824 55446 i
I*> 2407:ca40:30::/48	134715 9885 55824 4758 142502 i
I*> 2409::/32	134715 9885 55824 142500 i
I*> 2620:88:6000::/48	134715 9885 23855 23864 11537 10490 33600 i
I*> 2800:110:1018::/48	134715 9885 23855 23864 11537 27750 3597 4270 52442 i
I*> 2800:110:2200::/48	134715 9885 23855 23864 11537 27750 3597 4270 264630 i
I*> 2800:110:2800::/48	134715 9885 23855 23864 11537 27750 3597 4270 27875 i
I*> 2800:110:3400::/48	134715 9885 23855 23864 11537 27750 3597 4270 28068 i

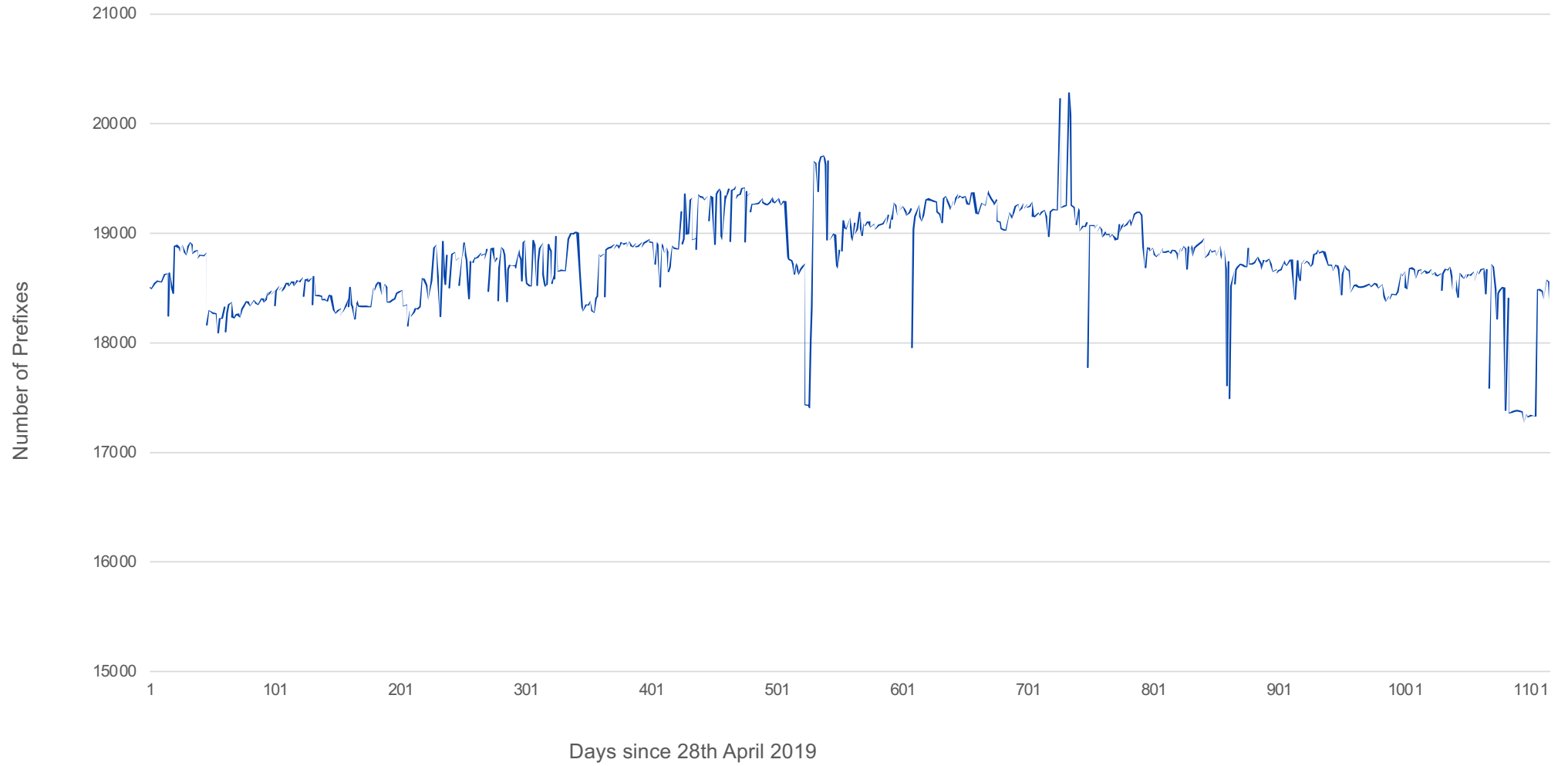




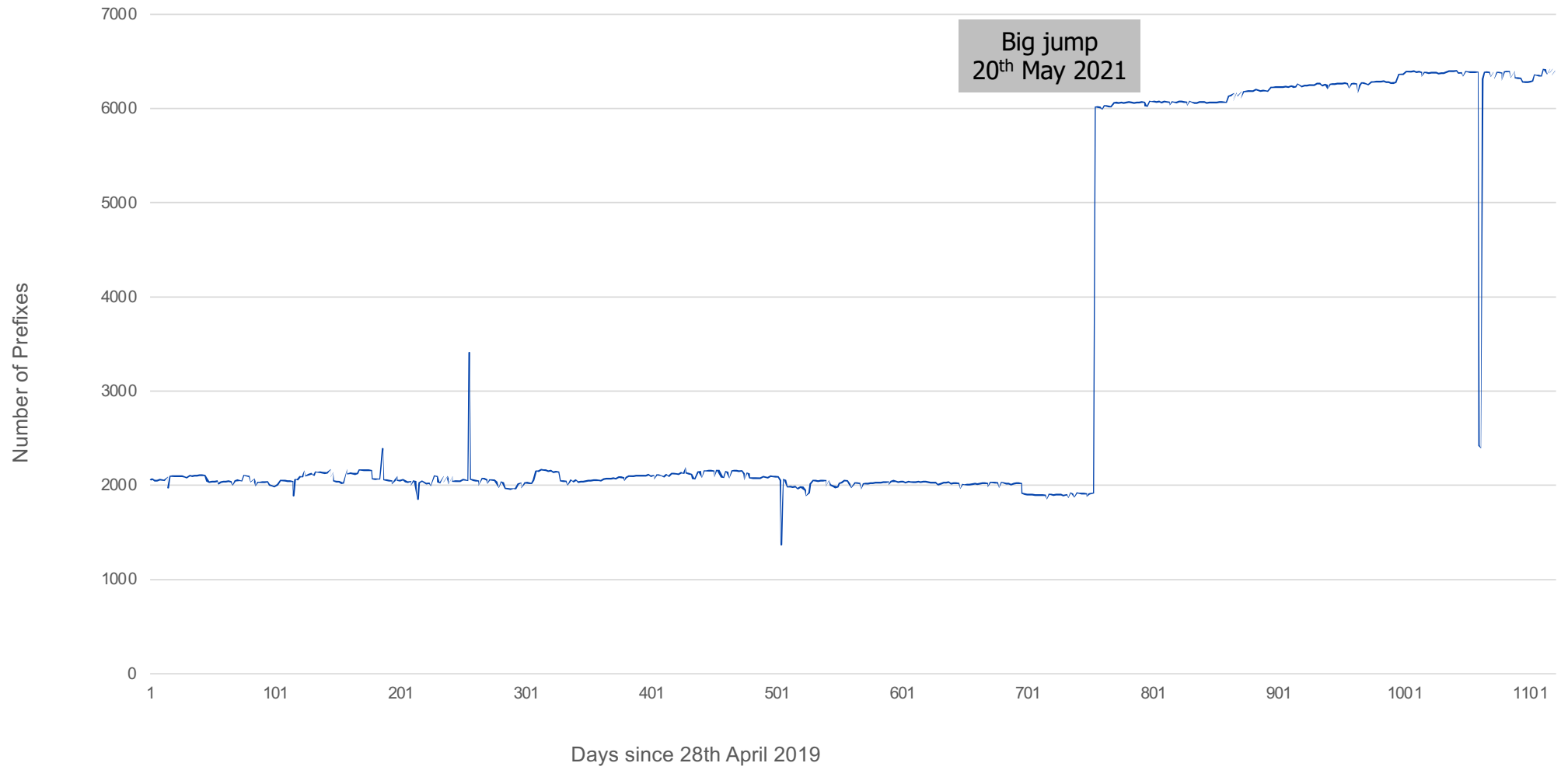
# ROAs vs RPKI Invalids

Prefix	Prefix Length	Origin-AS	Network	Path
2001:288::	32 - 32	1659	I*> 2001:288:5001::/48	134715 9885 23855 7660 24167 7539 1659 e
2001:288::	32 - 32	1659	I*> 2001:288:500b::/48	134715 9885 23855 7660 24167 7539 1659 e
2001:388::	32 - 40	7575	I*> 2001:388:cf85::/48	134715 9885 23855 7575 i
2001:e30:1100::	40 - 40	2697	I*> 2001:e30:1111::/48	134715 9885 55824 2697 i
2001:4408::	32 - 32	4758	I*> 2001:4408:1180::/44	134715 9885 55824 4758 ?
2001:4408::	32 - 32	4758	I*> 2001:4408:5d00::/44	134715 9885 55824 4758 ?
2001:4408::	32 - 32	4758	I*> 2001:4408:6200::/48	134715 9885 55824 4758 ?
2001:4408::	32 - 32	4758	I*> 2001:4408:6220::/48	134715 9885 55824 4758 ?
2001:48a8::	32 - 32	237	I*> 2001:48a8:68f7::/48	134715 9885 23855 23864 11537 237 231 229 i
2001:48a8::	32 - 32	237	I*> 2001:48a8:68fe::/48	134715 9885 23855 23864 11537 237 i
2400:a980::	29 - 29	133111	I*> 2400:a980::/32	134715 9885 23855 24490 24489 23911 23910 133111 i
2400:a980::	29 - 29	133111	I*> 2400:a980::/40	134715 9885 23855 24490 24489 23911 23910 133111 i
2400:a980::	29 - 29	133111	I*> 2400:a980:bf::/48	134715 9885 23855 24490 24489 23911 23910 133111 i
2400:a980::	29 - 29	133111	I*> 2400:a980:c1::/48	134715 9885 23855 24490 24489 23911 23910 133111 134169 i
<snip>			<snip>	
2400:a980::	29 - 29	133111	I*> 2400:a980:90ff::/48	134715 9885 23855 24490 24489 23911 23910 133111 i
2405:8a00::	32 - 32	55824	I*> 2405:8a00:bb::/48	134715 9885 55824 ?
2405:8a00::	32 - 32	55824	I*> 2405:8a00:217e::/48	134715 9885 55824 ?
2405:8a00::	32 - 32	55824	I*> 2405:8a00:401f::/48	134715 9885 55824 I
<snip>			<snip>	
2407:9a00::	32 - 32	55446	I*> 2407:9a00:1::/48	134715 9885 55824 55446 i
2407:ca40::	32 - 32	142502	I*> 2407:ca40:30::/48	134715 9885 55824 4758 142502 i
2409::	28 - 28	55824	I*> 2409::/32	134715 9885 55824 142500 i
2620:88:6000::	48 - 48	10490	I*> 2620:88:6000::/48	134715 9885 23855 23864 11537 10490 33600 i
2800:110::	32 - 48	4270	I*> 2800:110:1018::/48	134715 9885 23855 23864 11537 27750 3597 4270 52442 i
2800:110::	32 - 48	4270	I*> 2800:110:2200::/48	134715 9885 23855 23864 11537 27750 3597 4270 264630 i
2800:110::	32 - 48	4270	I*> 2800:110:2800::/48	134715 9885 23855 23864 11537 27750 3597 4270 27875 i
2800:110::	32 - 48	4270	I*> 2800:110:3400::/48	134715 9885 23855 23864 11537 27750 3597 4270 28068 i

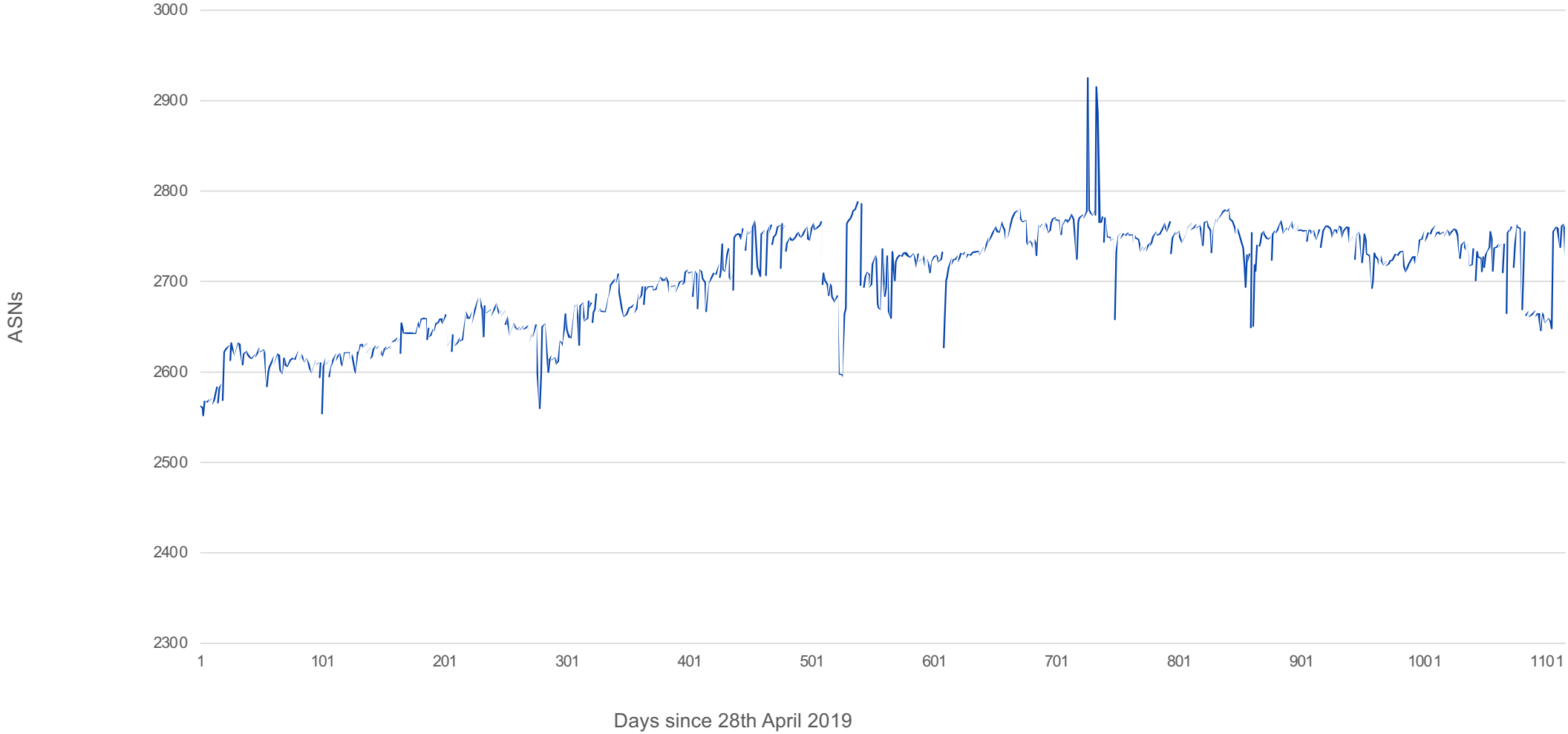
# Global R&E IPv4 Routing Table



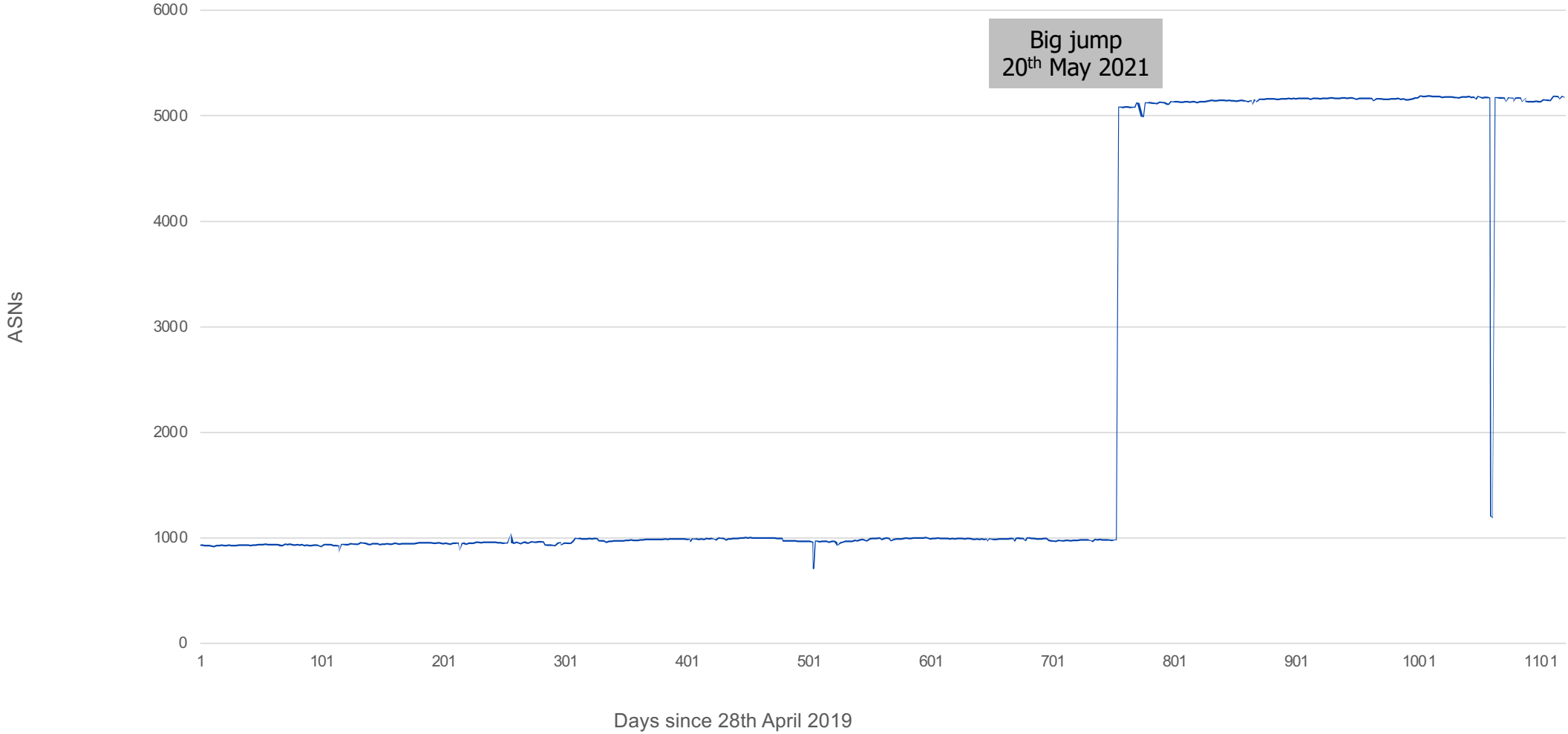
# Global R&E IPv6 Routing Table



# IPv4 AS Growth



# IPv6 AS Growth



# The big IPv6 jump?

- A jump of 4096 /32s and 4096 ASNs
- On 20<sup>th</sup> May 2021 **this** happened:

```
*> 240a:a000::/20      134715 9885 20965 23911 38272 i
*> 240a:a000::/32      134715 9885 24490 24489 23911 38255 142650 i
*> 240a:a001::/32      134715 9885 24490 24489 23911 38255 142651 i
*> 240a:a002::/32      134715 9885 24490 24489 23911 38255 142652 i
...
*> 240a:affd::/32      134715 9885 24490 24489 23911 38255 146743 i
*> 240a:affe::/32      134715 9885 24490 24489 23911 38255 146744 i
*> 240a:afff::/32      134715 9885 24490 24489 23911 38255 146745 i
```

```
AS20965 is GÉANT (Europe)
AS23911 is CNGI-CERNET (China)
AS38272 is CERNET
```

```
AS24490 is TEIN (Asia)
AS24489 is TEIN North
AS23911 is CNGI-CERNET
AS38255 is CERNET
```

```
inet6num: 240a:a000::/20
netname: FITI-CN
descr: China Education and Research Network (CERNET)
descr: FIT 3-220,
descr: Tsinghua University
country: CN
```

```
as-block: AS142650 - AS143163
descr: China Education and Research Network (CERNET)
descr: CERNET AS Block for FITI Slices
country: CN
...
as-block: AS146234 - AS146745
descr: China Education and Research Network (CERNET)
descr: CERNET AS Block for FITI Slices
country: CN
```

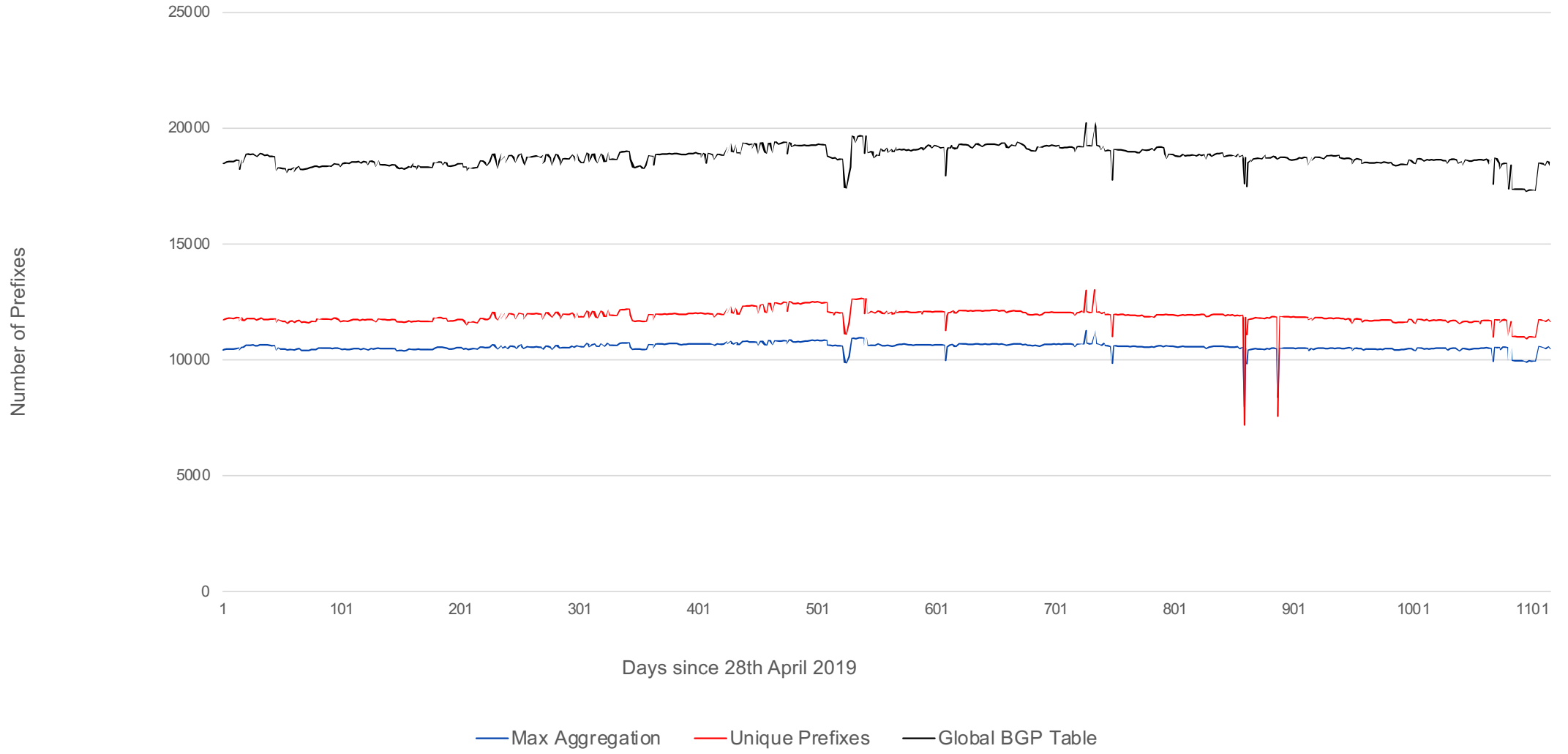
– CERNET's FITI Slices announced



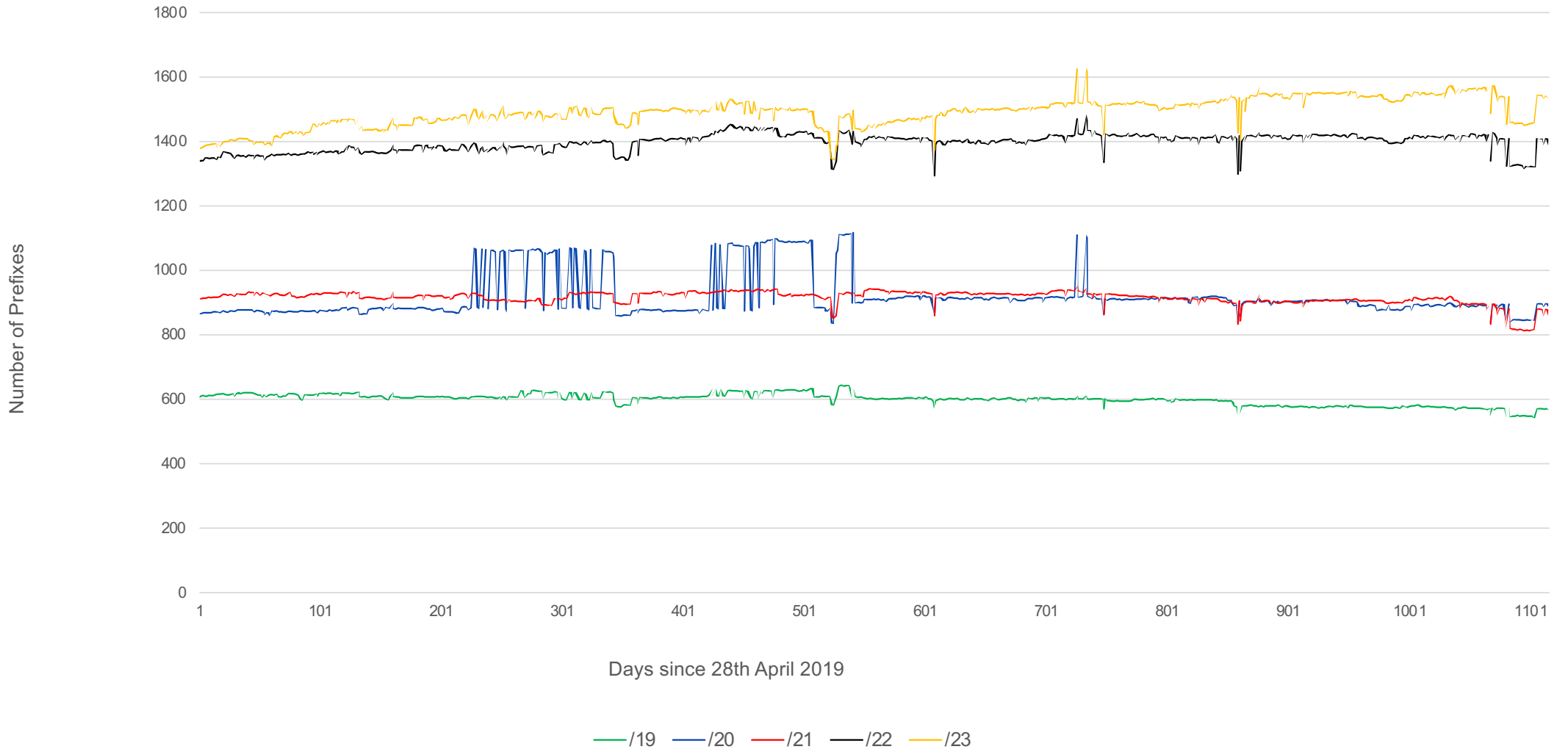
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# IPv4 Max Aggregation vs Unique Prefixes

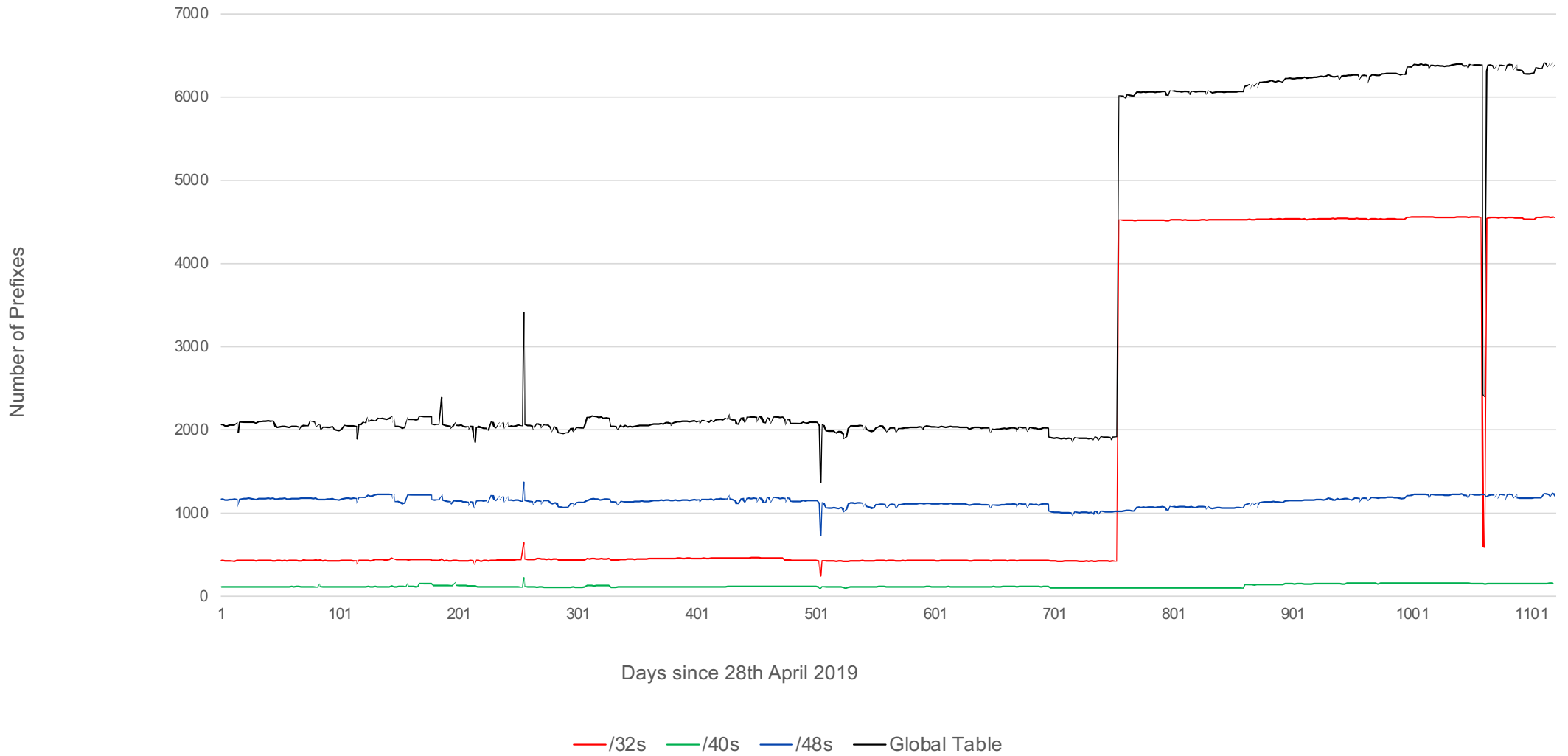


# IPv4 Prefix sizes announced

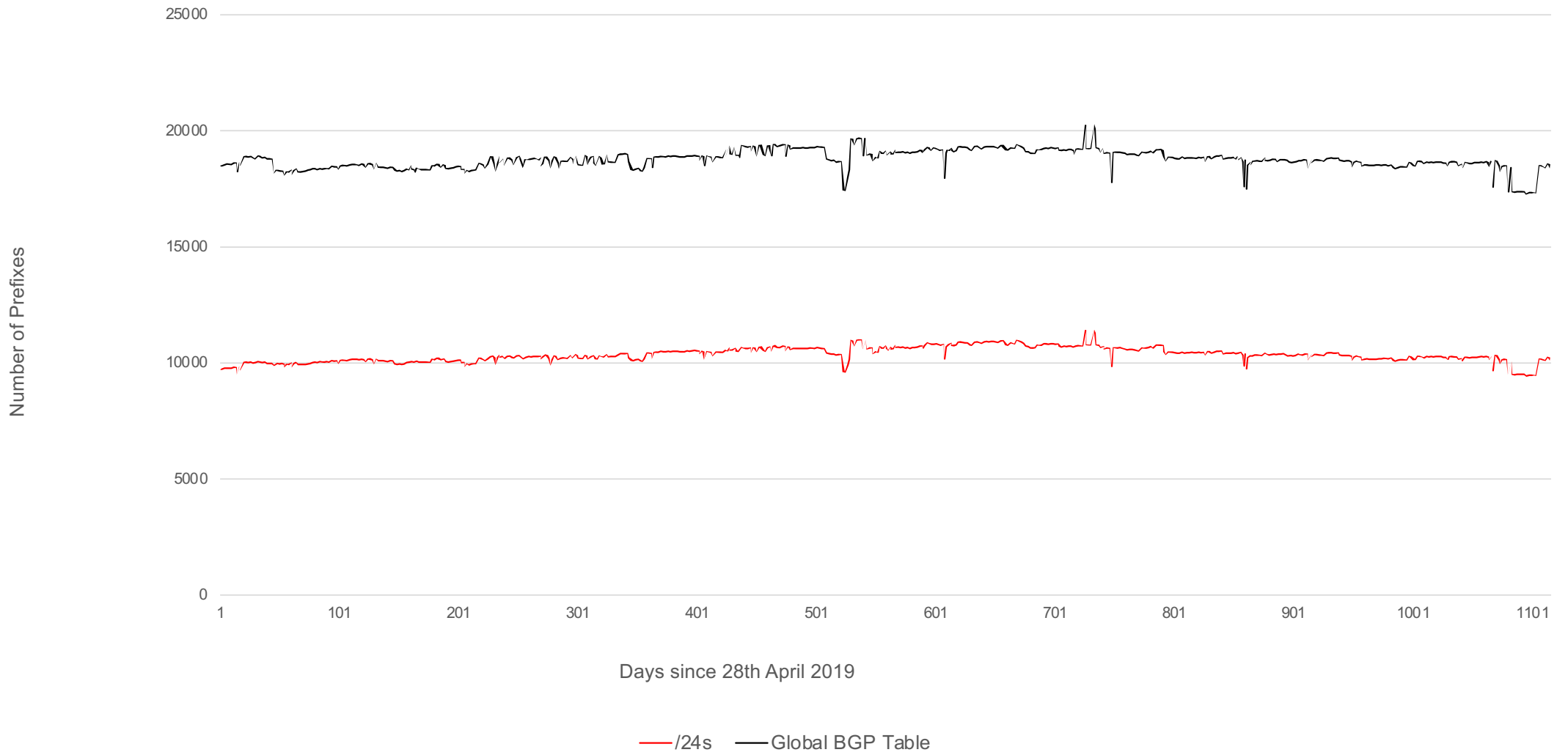




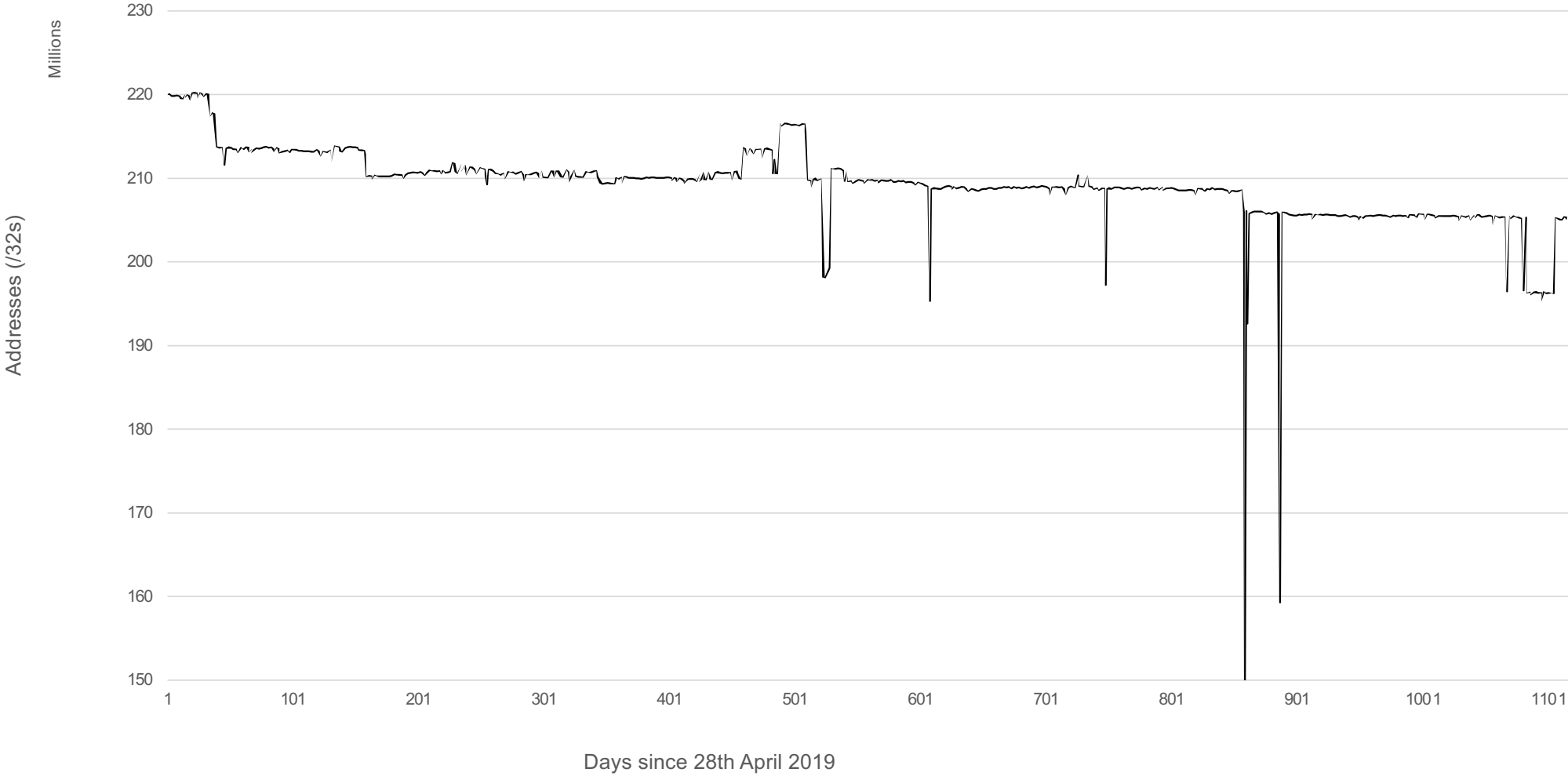
# IPv6 prefix sizes announced



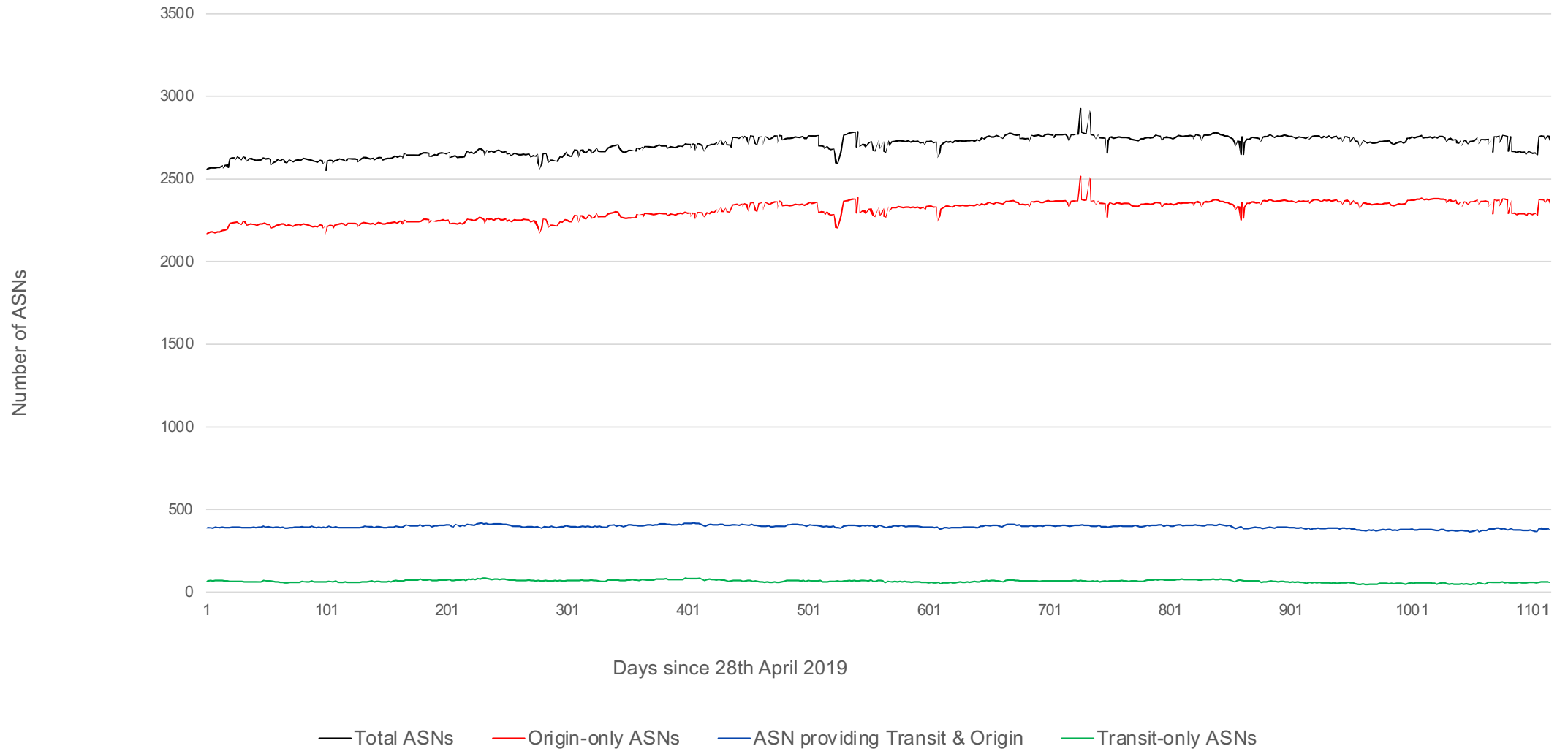
# IPv4 /24s announced



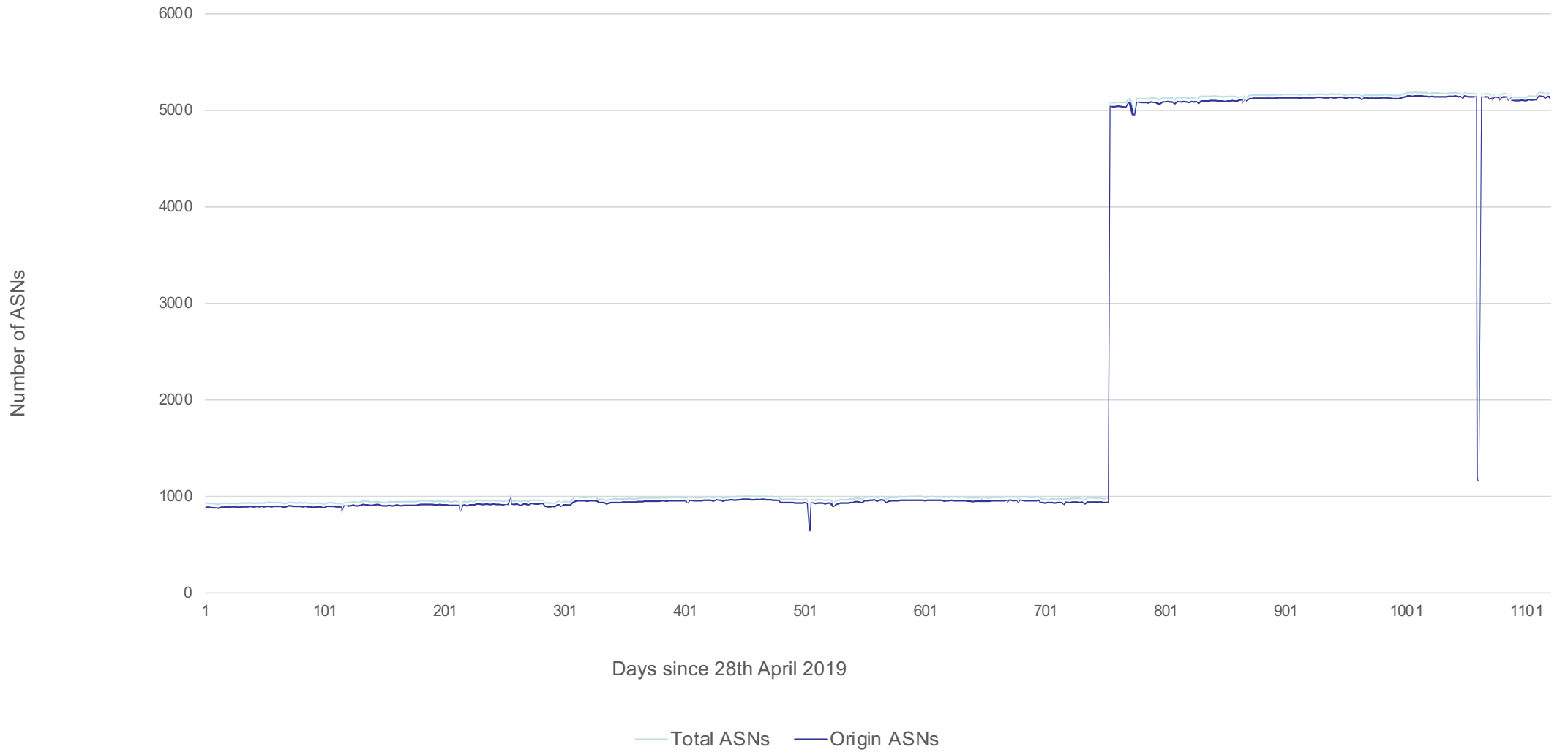
# IPv4 Address Space announced



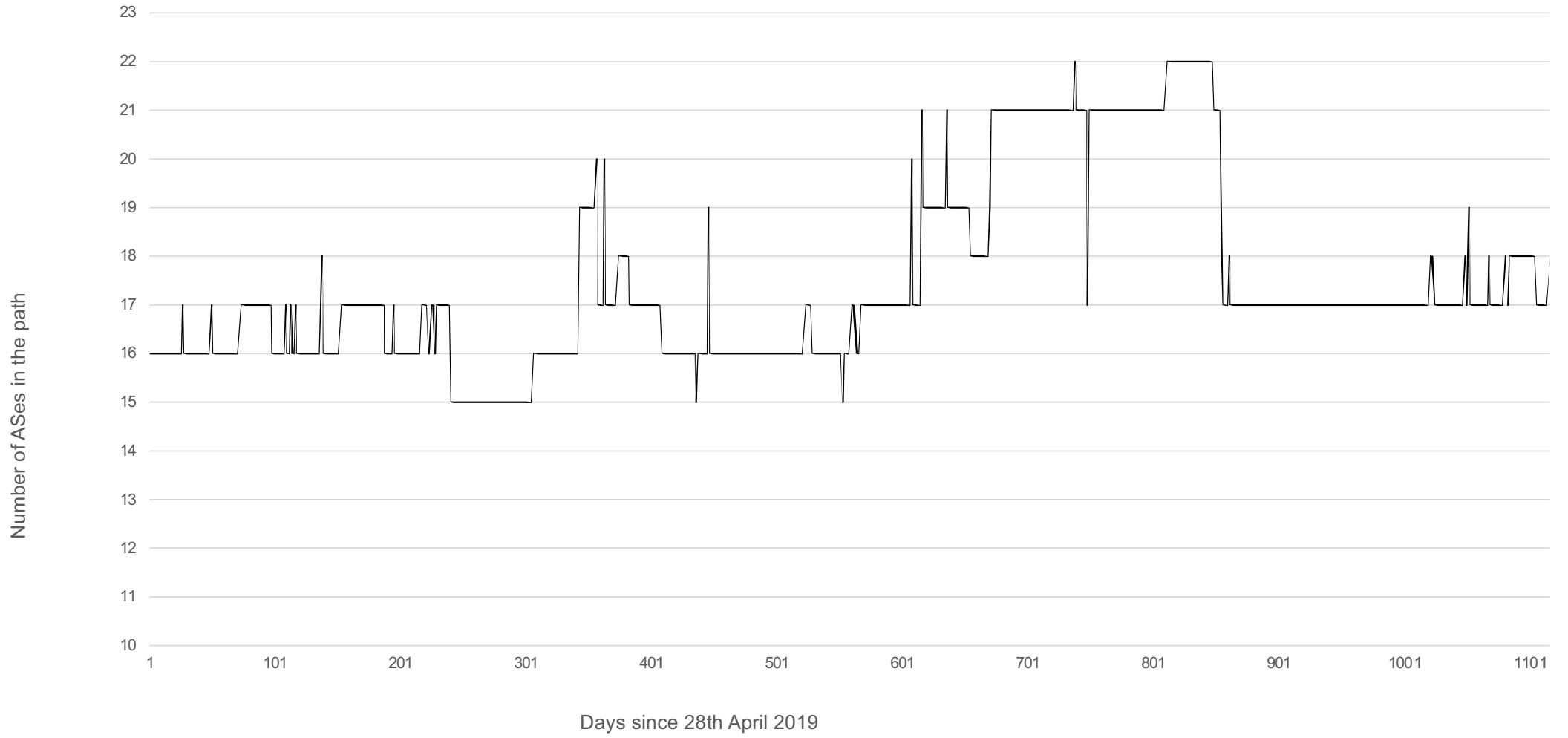
# IPv4 AS Announcements



# IPv6 AS Announcements



# IPv4 Maximum AS Path Length



# Big prepends

- What is SURFNET hoping to achieve?

```
v*> 145.100.118.0/23      134715 9885 23855 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149 i
```

- Does adding 10 prepends of 1149 give traffic engineering outcomes? 😊

- Routeviews shows:

```
route-views>sh ip bgp 145.100.118.0/23 | i 1149
 1221 4637 6461 6461 6461 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149
 3356 3257 1103 1103 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149
 3549 3356 3257 1103 1103 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149
<snip>
 3267 2603 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149
 20130 6939 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149
 3333 20473 20473 20473 20473 1149
 7660 22388 11537 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149
 6939 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149 1149
 8283 20473 20473 20473 20473 1149
 4901 11537 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149
 20080 11537 1103 1133 1149 1149 1149 1149 1149 1149 1149 1149 1149
```

- Non-prepended path is then 3x prepended by AS20473 (The Constant Company, LLC)

# Looking at Deaggregation

- CIDR Report
  - [www.cidr-report.org](http://www.cidr-report.org)
  - Encourages aggregation following CIDRisation of Internet
  - Today: extensive suite of reports and tools covering state of BGP table
- Routing Report
  - BGP table status on per RIR basis
  - Original CIDR Report and a whole lot more



# Deaggregation Factor

- Routing Report
  - One summary takes BGP table and aggregates prefixes by origin AS
    - Called “Max Aggregation” in report
  - Global R&E and per RIR basis
    - <https://bgp.nsrc.org/REN/DrukREN/>
- Calculates **Deaggregation** Factor:
  - Measure of Routing Table size/Aggregated Size
  - Global value has been increasing slowly and steadily since “records began”

# May 2022

- **Total Prefixes**

- Global R&E BGP Table

- 18.4k prefixes

- North America

- 8.0k prefixes

- Europe & Middle East

- 3.5k prefixes

- Asia & Pacific

- 4.7k prefixes

- Latin America & Caribbean

- 1.2k prefixes

- Africa

- 0.9k prefixes

- **Deaggregation Factor**

- Global Average

- 1.78

- North America

- 1.71

- Europe & Middle East

- 1.23

- Asia & Pacific

- 2.08

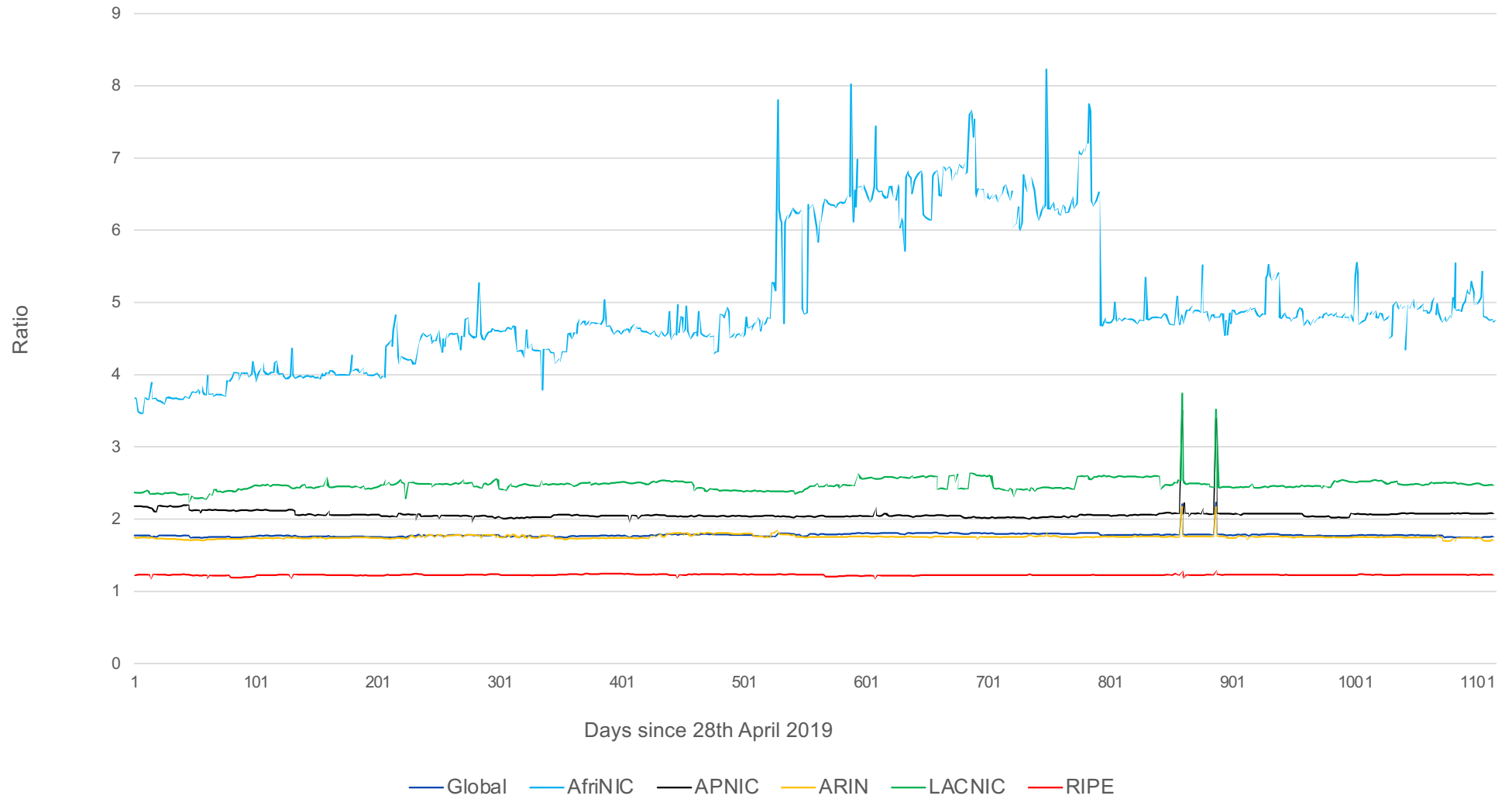
- Latin America & Caribbean

- 2.45

- Africa

- 4.77

# IPv4 Deaggregation: RIR Regions vs Global



# Africa Deaggregation

- 27<sup>th</sup> June 2021, deaggregation ratio changed from 6.53 to 4.66
  - KENET did some aggregation: 409 routes down to 99 routes

26<sup>th</sup> June:

ASN	No of nets	/20 equiv	MaxAgg	Description
36914	409	82	3	KENET-AS, KE
2018	324	319	74	TENET-1, ZA
327687	137	28	3	RENU, UG
2561	74	5	34	EUN, EG
8094	55	48	4	PUKNET, ZA

27<sup>th</sup> June:

ASN	No of nets	/20 equiv	MaxAgg	Description
2018	324	319	74	TENET-1, ZA
327687	137	28	3	RENU, UG
36914	99	82	3	KENET-AS, KE
2561	74	5	34	EUN, EG
8094	55	48	4	PUKNET, ZA



## Global IPv4 Aggregation Savings Summary

ASN	No of Nets	Savings	Description
7497	432	408	CSTNET-AS-AP Computer Network Information Cente
2018	376	302	TENET-1, ZA
36914	215	212	KENET-AS, KE
5786	200	199	UPRENET, PR
58647	175	173	KAGAWAU-AS Kagawa University, JP
4758	159	158	NICNET-VSNL-BOARDER-AP National Informatics Cen
8895	138	134	ISU Internet Services Unit ISU, SA
18558	131	127	NETBLK-RCOEK, US
1916	156	111	Rede Nacional de Ensino e Pesquisa, BR
55824	137	108	NKN-CORE-NW NKN Core Network, IN
2920	107	101	LACOE, US
23024	114	97	OCDE, US
32531	91	90	FORDHAM-UNIVERSITY, US
28391	152	86	Universidad Juarez Autonoma de Tabasco, MX
1736	80	79	MU-AS, US
4621	78	68	UNINET-AS-AP UNINET-, TH
21976	85	67	NJEDGE-NET, US
4762	65	64	MAHIDOL-BORDER-AS Mahidol University, Thailand,
3	78	63	MIT-GATEWAYS, US
2152	152	62	CSUNET-NW, US

<https://bgp.nsrc.org/REN/DrukREN/data-CIDRnet>

# RPKI – IPv4

- ASREN, Janet, MARWAN, REANNZ, UbuntuNet all report zero invalid routes!
  - Assuming they have implemented Route Origin Validation
  - What is stopping the other R&E networks from implementing ROV?
- Depending on where you look, the Global IPv4 table shows:

<u>Site</u>	<u>Prefixes</u>	<u>ASNs</u>	<u>Valid</u>	<u>Invalid</u>	<u>NotFound</u>
AARNET	892907	73152	327853	3092	561962
Uni of Guam	913472	73197	342602	2798	568072
London	883688	72990	327462	1183	555043
RENU	915504	73208	343053	2819	569632
Singapore	883680	72986	327463	1183	555034
USP	892862	73215	327814	3102	561946



# RPKI – IPv6

- ASREN, Janet, MARWAN, REANNZ, URAN all report zero invalid routes!
  - Assuming they have implemented Route Origin Validation
  - What is stopping the other R&E networks from implementing ROV?
- Depending on where you look, the Global IPv6 table shows:

<u>Site</u>	<u>Prefixes</u>	<u>ASNs</u>	<u>Valid</u>	<u>Invalid</u>	<u>NotFound</u>
AARNET	154453	28807	62709	1043	90701
CANARIE	148432	28702	62474	170	85788
Uni of Guam	144466	28295	60760	580	83126
London	144878	28237	61259	670	82949
RENU	151917	28801	63725	1958	86234
Singapore	144869	28232	61249	674	82946
USP	153336	28760	62611	24	90701
WACREN	142865	28166	60024	150	82691
ZAMREN	141443	28164	58000	222	83221



# URAN

- Connectivity variable as from 3<sup>rd</sup> March
  - RETN path had MTU issues – BGP feed went down
  - RETN path last used on 19<sup>th</sup> April
  - Moldova path to GÉANT returned on 20<sup>th</sup> April
  - Poland path to GÉANT returned on 1<sup>st</sup> May

Start: 2022-02-15T17:10:01+0000								
		Loss%	Snt	Last	Avg	Best	Wrst	StDev
21.	-- ae7.mx1.fra.de.geant.net	0.0%	10	164.2	164.5	164.0	166.6	0.8
22.	-- ae0.mx1.poz.pl.geant.net	0.0%	10	179.7	180.2	179.7	184.4	1.5
23.	-- ae3.rt1.kie.ua.geant.net	0.0%	10	195.9	197.9	195.6	216.8	6.6
24.	-- vlan311-alias.kv-r10.uran.ua	0.0%	10	196.1	196.2	196.1	197.0	0.3

Start: 2022-03-03T17:10:02+0000								
		Loss%	Snt	Last	Avg	Best	Wrst	StDev
21.	-- ae7.mx1.fra.de.geant.net	0.0%	10	164.0	164.3	164.0	165.2	0.3
22.	-- ae9.mx1.buc.ro.geant.net	0.0%	10	189.6	189.8	189.6	190.5	0.3
23.	-- ae3.rt1.chi.md.geant.net	0.0%	10	196.5	196.5	196.2	197.7	0.5
24.	-- ae1.rt2.chi.md.geant.net	0.0%	10	196.2	196.3	196.2	196.5	0.1
25.	-- ae3.rt2.kie.ua.geant.net	0.0%	10	206.1	207.7	206.0	222.5	5.2
26.	-- vlan311-alias.kv-r10.uran.ua	0.0%	10	206.4	207.2	206.4	208.6	1.0

Start: 2022-03-10T17:10:01+0000								
		Loss%	Snt	Last	Avg	Best	Wrst	StDev
8.	-- BR2.Amsterdam1.surf.net	0.0%	10	157.0	156.1	153.1	167.8	4.4
9.	-- ae1-6.RT.NTL.KIV.UA.retn.net	0.0%	10	232.0	210.4	207.8	232.0	7.6
10.	-- vlan311-alias.kv-r10.uran.ua	0.0%	10	209.6	209.9	208.1	222.7	4.5

Start: 2022-03-12T17:10:01+0000								
		Loss%	Snt	Last	Avg	Best	Wrst	StDev
21.	-- ae7.mx1.fra.de.geant.net	0.0%	10	164.2	164.6	164.2	165.9	0.5
22.	-- ae9.mx1.buc.ro.geant.net	0.0%	10	189.8	193.1	189.6	206.5	6.9
23.	-- ae3.rt1.chi.md.geant.net	0.0%	10	196.4	196.4	196.2	196.6	0.1
24.	-- ae1.rt2.chi.md.geant.net	0.0%	10	196.5	196.5	196.3	196.7	0.1
25.	-- ae3.rt2.kie.ua.geant.net	0.0%	10	206.1	206.3	206.0	206.5	0.2
26.	-- vlan311-alias.kv-r10.uran.ua	0.0%	10	206.7	207.3	206.6	211.7	1.5





# IPv4 Observations

- Routing table is quite stable
  - Slight decline, plus decline of overall address space announced
  - (Commodity Internet showing continued linear growth)
- /24 announcements quite stable
- Overall global deaggregation ratio is stable apart from Africa
  - Late 2020: KENET deaggregated
  - Mid 2021: KENET reaggregated
- Some RPKI Invalids
  - What's stopping all RENOs implementing ROV ?

# IPv6 Observations

- Global R&E IPv6 table
  - Not much happening:
    - No IPv6 roll out in R&E?
    - Or has R&E fully deployed IPv6?
  - Then on May 20<sup>th</sup> 2021:
    - CERNET announcement of 4096 /32s from 4096 ASNs
  - In contrast, global table (commodity) is growing quickly
    - Perhaps even exponentially 🤯
- Surprising number of RPKI Invalids
  - What's stopping all RENs implementing ROV ?

# Global R&E Routing Table Update

Questions?



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