Global R&E Routing Table Update

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vPhNOG 2.0

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Motivation

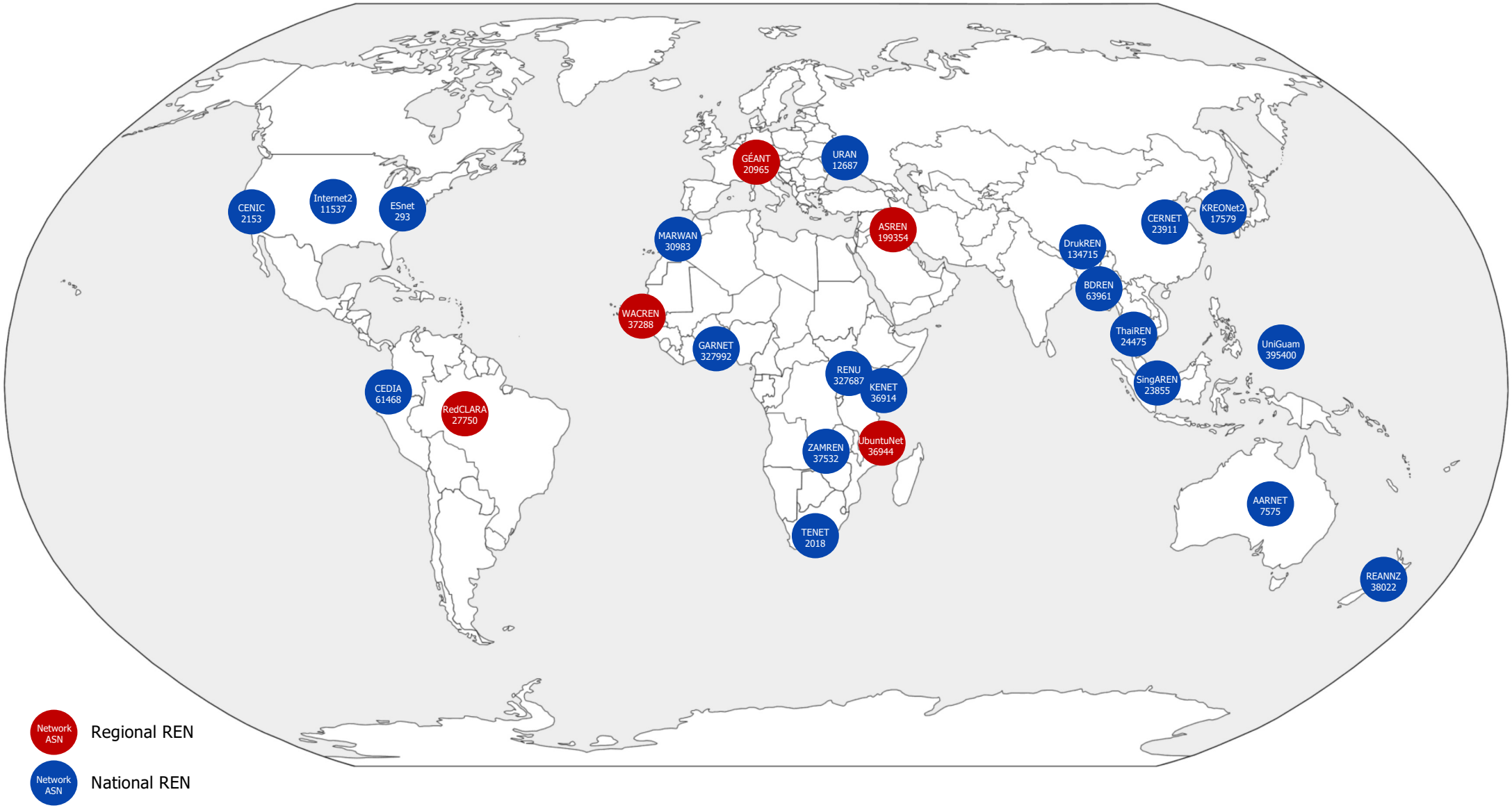
- 1998: No one was publishing any Internet routing table analysis
  - Only CIDR-Report reporting on top 20 contributors to routing table, and top 20 bad aggregators
- 1999: Started weekly report looking at Global Internet Routing Table
  - Routing table size
  - CIDR-Report style reporting on a per-RIR 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


GÉANT
20965
URAN
12687
CENIC
2153
Internet2
11537
ESnet
293
MARWAN
30983
ASREN
199354
CERNET
23911
KREONet2
17579
DrukREN
134715
BDREN
63961
WACREN
37288
ThaiREN
24475
UniGuam
395400
GARNET
327992
RENU
327687
KENET
36914
SingAREN
23855
CEDIA
61468
RedCLARA
27750
ZAMREN
37532
UbuntuNet
36944
AARNET
7575
TENET
2018
REANNZ
38022
Network
ASN
Regional REN
Network
ASN
National REN

R&E Table Size Summary

AS Number	Network Name	IPv4	IPv6
7575	AARNET	17802	6065
199354	ASREN	14503	5612
63961	BDREN	19036	5655
61468	CEDIA	21832	6788
2153	CENIC	22018	6139
23911	CERNET	17191	1464
134715	DrukREN	18868	6074
293	ESnet (local only)	159	163
327992	GARNET (local IPv4, no IPv6)	29	N/A
20965	GÉANT	18764	6117
11537	Internet2	22256	6808
36914	KENET	17160	2404
17579	KREOnet2 (local only)	623	221
30983	MARWAN	14506	5616
38022	REANNZ	18796	6287
27750	RedCLARA	18483	6151
327687	RENU (full)	840316	124783
23855	SingAREN	19168	6199
2018	TENET	16333	6513
24475	ThaiREN (local only)	376	2
36944	UbuntuNet Alliance	17795	6044
395400	University of Guam	23098	5889
12687	URAN	18737	6112
37288	WACREN (full IPv6)	18485	121001
37532	ZAMREN (local IPv4, full IPv6)	139	124494

R&E View IPv4 differences

Internet 2

ASN	No of nets	/20 equiv	MaxAgg	Description
16509	2421	4433	909	AMAZON-02, US
2907	619	2155	456	SINET-AS Research Organization of Infor
14618	491	3966	363	AMAZON-AES, US
7497	434	215	29	CSTNET-AS-AP Computer Network Informati
2018	324	319	74	TENET-1, ZA

University of Guam

ASN	No of nets	/20 equiv	MaxAgg	Description
16509	2504	4446	983	AMAZON-02, US
2907	630	2155	456	SINET-AS Research Organization of Infor
14618	491	3966	363	AMAZON-AES, US
7497	434	215	29	CSTNET-AS-AP Computer Network Informati
7575	355	331	129	AARNET-AS-AP Australian Academic and Re

ASREN

ASN	No of nets	/20 equiv	MaxAgg	Description
2907	618	2155	455	SINET-AS Research Organization of Infor
7497	423	209	20	CSTNET-AS-AP Computer Network Informati
2018	321	319	72	TENET-1, ZA
680	273	1996	235	DFN Verein zur Foerderung eines Deutsch
376	230	180	154	RISQ-AS, CA

CEDIA

ASN	No of nets	/20 equiv	MaxAgg	Description
16509	1631	1534	466	AMAZON-02, US
15169	738	3278	65	GOOGLE, US
2907	630	2155	456	SINET-AS Research Organization of Infor
14618	490	3966	362	AMAZON-AES, US
7497	434	215	29	CSTNET-AS-AP Computer Network Informati

TENET

ASN	No of nets	/20 equiv	MaxAgg	Description
2907	607	2155	455	SINET-AS Research Organization of Infor
7497	434	215	29	CSTNET-AS-AP Computer Network Informati
2018	324	319	74	TENET-1, ZA
7896	245	51	7	NU-AS, US
376	235	180	158	RISQ-AS, CA

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Analysis Summaries

- Data in the following graphics taken primarily from DrukREN
  - R&E feed dating from 28th April 2019
  - Most informative to show trends
- In future:
  - Comparisons between DrukREN and other R&E networks
  - Interesting paths
  - Etc 😀

IPv4 Routing Report 7th July 2021

BGP routing table entries examined:	18808
Prefixes after maximum aggregation (per Origin AS):	10572
Deaggregation factor:	1.78
Unique aggregates announced (without unneeded subnets):	11927
Total ASes present in the Internet Routing Table:	2750
Prefixes per ASN:	6.84
Origin-only ASes present in the Internet Routing Table:	2350
Origin ASes announcing only one prefix:	1105
Transit ASes present in the Internet Routing Table:	400
Transit-only ASes present in the Internet Routing Table:	73
Average AS path length visible in the Internet Routing Table:	5.5
Max AS path length visible:	21
Max AS path prepend of ASN (10497)	11
Prefixes from unregistered ASNs in the Routing Table:	18
Number of instances of unregistered ASNs:	18
Special use prefixes present in the Routing Table:	1
Prefixes being announced from unallocated address space:	3
Number of addresses announced to Internet:	208679424
Equivalent to 12 /8s, 112 /16s and 50 /24s	
Total number of prefixes smaller than registry allocations:	1990

Global IPv4 per AS prefix count summary

ASN	No of nets	/20 equiv	Max Agg	Description
2907	607	2155	455	SINET-AS Research Organization of Infor
7497	434	215	29	CSTNET-AS-AP Computer Network Informati
2018	324	319	74	TENET-1, ZA
680	273	1996	235	DFN Verein zur Foerderung eines Deutsch
7896	245	51	7	NU-AS, US
376	235	180	158	RISQ-AS, CA
668	209	702	180	DNIC-AS-00668, US
5786	201	16	1	UPRENET, PR
1237	189	75	137	KREONET-AS-KR KISTI, KR
786	187	1787	185	JANET Jisc Services Limited, GB
7575	180	330	126	AARNET-AS-AP Australian Academic and Re
1916	178	207	41	Associacao Rede Nacional de Ensino e Pe
58647	164	18	2	KAGAWAU-AS Kagawa University, JP
2152	159	507	91	CSUNET-NW, US
4758	156	16	1	NICNET-VSNL-BOARDER-AP National Informa
28391	152	10	66	Universidad Juarez Autonoma de Tabasco,
8895	141	24	4	ISU Internet Services Unit ISU, SA
18558	137	18	4	NETBLK-RCOEK, US
327687	136	28	3	RENU, UG
55824	131	19	25	NKN-CORE-NW NKN Core Network, IN

Unassigned resources

- Some unassigned address space appearing
  - Currently 3 unassigned prefixes in IPv4 routing table
- Use of unassigned ASNs is also an issue
  - Currently 4 unassigned ASNs in use

List of Unassigned addresses

```
Unassigned Network     ASN Information  AS Name
164.160.240.0/20     Origin:    328439  UNASSIGNED
                    Transit:    327992  GHANAIAN-ACADEMIC-AND-RESEARCH-NETWORK,
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:     20965  GEANT The GEANT IP Service, NL
```

- Some notes about these:
  - 164.160.240.0/24 is part of AfriNIC unassigned reserve
  - 192.31.196.0/24 is listed as “IANA Reserved”
  - 192.88.99.0/24 is the deprecated 6to4 relay address (RFC7526)
    - Please do NOT use tunnels for IPv6!!
- Generally considered unsafe to transit unassigned address space

List of Unregistered Origin ASNs

Bad AS	Designation	Net Originated	Transit AS	Transit AS Name
36843	UNALLOCATED	64.56.80.0/23	11096	FLORIDANET, US
19658	UNALLOCATED	65.205.131.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	108.59.20.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	108.59.23.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	131.91.183.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	131.91.252.0/22	11096	FLORIDANET, US
36843	UNALLOCATED	146.201.218.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	146.201.219.0/24	11096	FLORIDANET, US
22063	UNALLOCATED	153.10.0.0/16	2152	CSUNET-NW, US
36843	UNALLOCATED	162.223.23.0/24	11096	FLORIDANET, US
328439	UNALLOCATED	164.160.240.0/20	327992	GHANAIAN-ACADEMIC-AND-RESEAR
64542	PRIVATE	192.12.235.0/24	2843	LIUNET, SE
64542	PRIVATE	192.36.54.0/24	2843	LIUNET, SE
19658	UNALLOCATED	199.27.241.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	199.44.67.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	199.44.72.0/24	11096	FLORIDANET, US
36843	UNALLOCATED	206.224.200.0/21	11096	FLORIDANET, US
36843	UNALLOCATED	206.224.208.0/20	11096	FLORIDANET, US

- Some notes about these:
  - AS 36843, AS 22063, AS328439 and AS 19658 are not registered
  - AS 64542 is a Private ASN – must not be routed
  - Why is transit provider giving transit to unregistered Internet resources?

Number of IPv4 prefixes announced by prefix length

/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	/14:38	/15:120	/16:2066
/17:386	/18:420	/19:627	/20:1082	/21:938	/22:1445	/23:1519	/24:10658
/25:0	/26:0	/27:10	/28:0	/29:3	/30:8	/31:0	/32:0

7th July 2019 ↑

7th July 2021 ↓

/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	/14:37	/15:118	/16:2053
/17:382	/18:419	/19:594	/20:914	/21:911	/22:1404	/23:1502	/24:10442
/25:0	/26:0	/27:0	/28:0	/29:0	/30:0	/31:0	/32:0

What about IPv6 ?

Table Size	6076
Total number of ASNs	5131
Total number of Origin ASNs	5088
Number of /32s	4526
Number of /48s	1077
Number of prefixes >/48	0 ← Upstreams Filtering 😀
Number of prefixes >/32 and </48	410
Number of prefixes >/16 and </32	77

Global IPv6 per AS prefix count summary

ASN	No of Nets	Description
7497	157	CSTNET-AS-AP Computer Network Information Center, CN
55824	79	NKN-CORE-NW NKN Core Network, IN
45773	63	HECPERN-AS-PK PERN AS Content Servie Provider, Islamabad, Pa
4758	59	NICNET-VSNL-BOARDER-AP National Informatics Centre, IN
61468	35	CEDIA, EC
1916	16	Associacao Rede Nacional de Ensino e Pesquisa, BR
262156	16	Universidad Nacional de Rosario, AR
24151	15	CNNIC-CRITICAL-AP China Internet Network Infomation Center,
4608	14	APNIC-SERVICES Asia Pacific Network Information Centre, AU
559	13	SWITCH Peering requests: peering@switch.ch, CH
327687	13	RENU, UG
680	10	DFN Verein zur Foerderung eines Deutschen Forschungsnetzes e
786	10	JANET Jisc Services Limited, GB
2018	10	TENET-1, ZA
3477	10	NOAA-NWAVE, US
58834	10	GCABLENET Guangdong Cable Corporation Limited, CN
271	9	BCNET-AS, CA
6262	9	CSIRO Commonwealth Scientific and Industrial, AU
3	8	MIT-GATEWAYS, US
7575	8	AARNET-AS-AP Australian Academic and Research Network AARNet

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	/29:39	/30:7	/31:0
/32:433	/33:29	/34:15	/35:19	/36:33	/37:8	/38:14	/39:2
/40:135	/41:6	/42:8	/43:2	/44:95	/45:21	/46:4	/47:13
/48:1181	/49 → /128: FILTERED by Upstream						

7th July 2019 ↑

7th July 2021 ↓

/16:0	/17:0	/18:0	/19:0	/20:2	/21:1	/22:0	/23:0
/24:2	/25:0	/26:1	/27:1	/28:5	/29:51	/30:12	/31:2
/32:4526	/33:30	/34:14	/35:23	/36:36	/37:10	/38:11	/39:1
/40:99	/41:7	/42:11	/43:2	/44:109	/45:22	/46:5	/47:16
/48:1077	/49 → /128: FILTERED by Upstream						

Global R&E IPv4 Routing Table

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Days since 28th April 2019

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Global R&E IPv6 Routing Table

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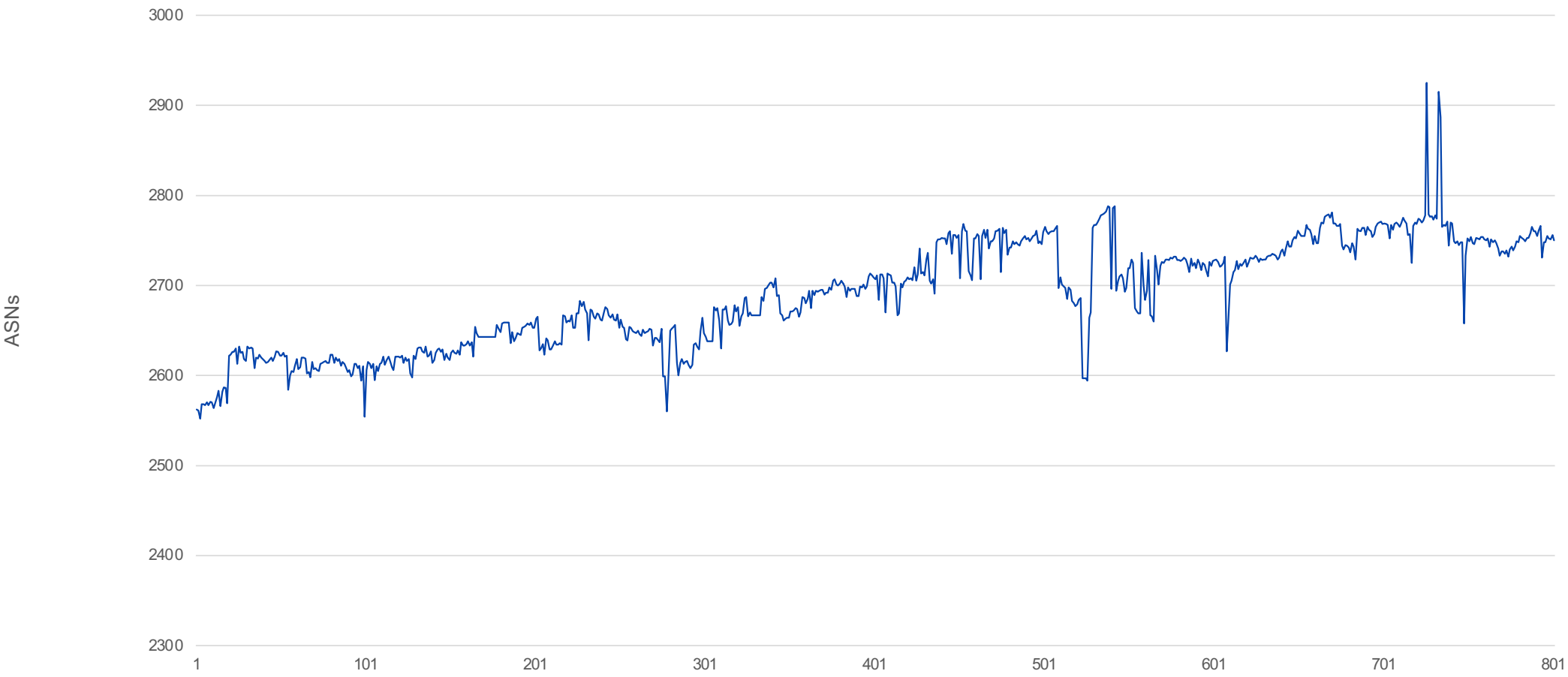
IPv4 AS Growth



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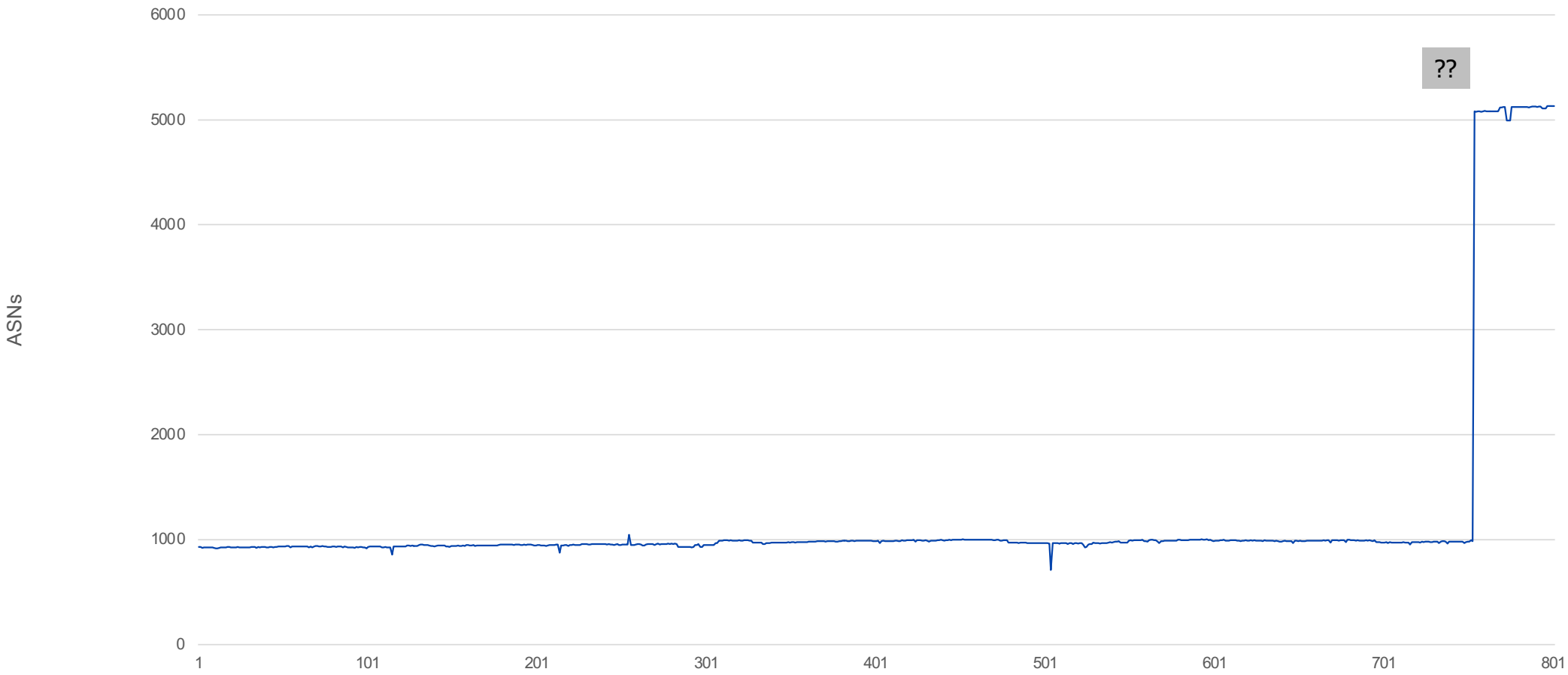
IPv6 AS Growth



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The big IPv6 jump?

- A jump of 4096 /32s and 4096 ASNs
- On 20th 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
```

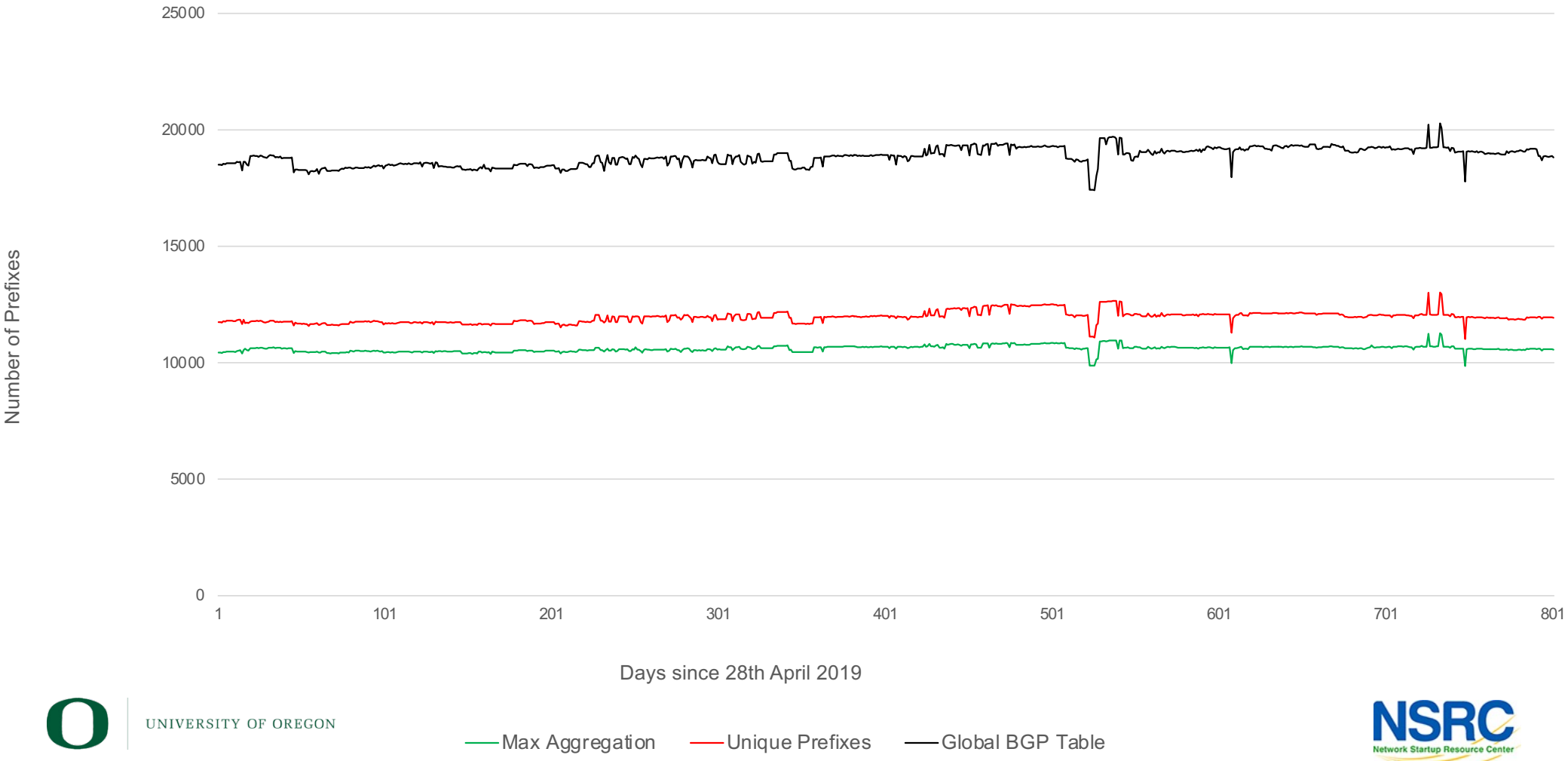
```
AS20965 is GÉANT (Europe)
AS23911 is CNGI-CERNET (China)
AS38272 is CERNET

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

IPv4 Max Aggregation vs Unique Prefixes



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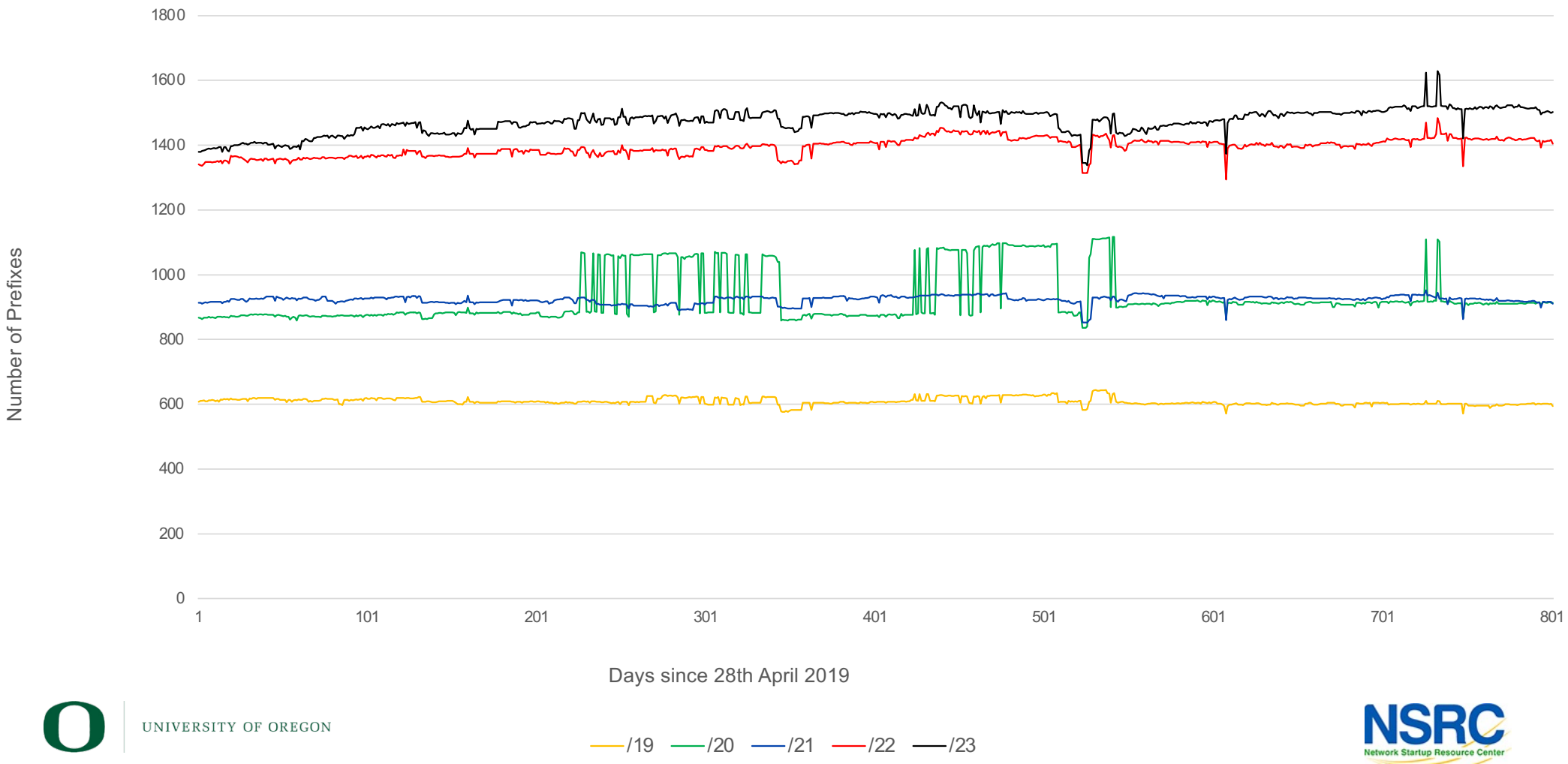
IPv4 Prefix sizes announced



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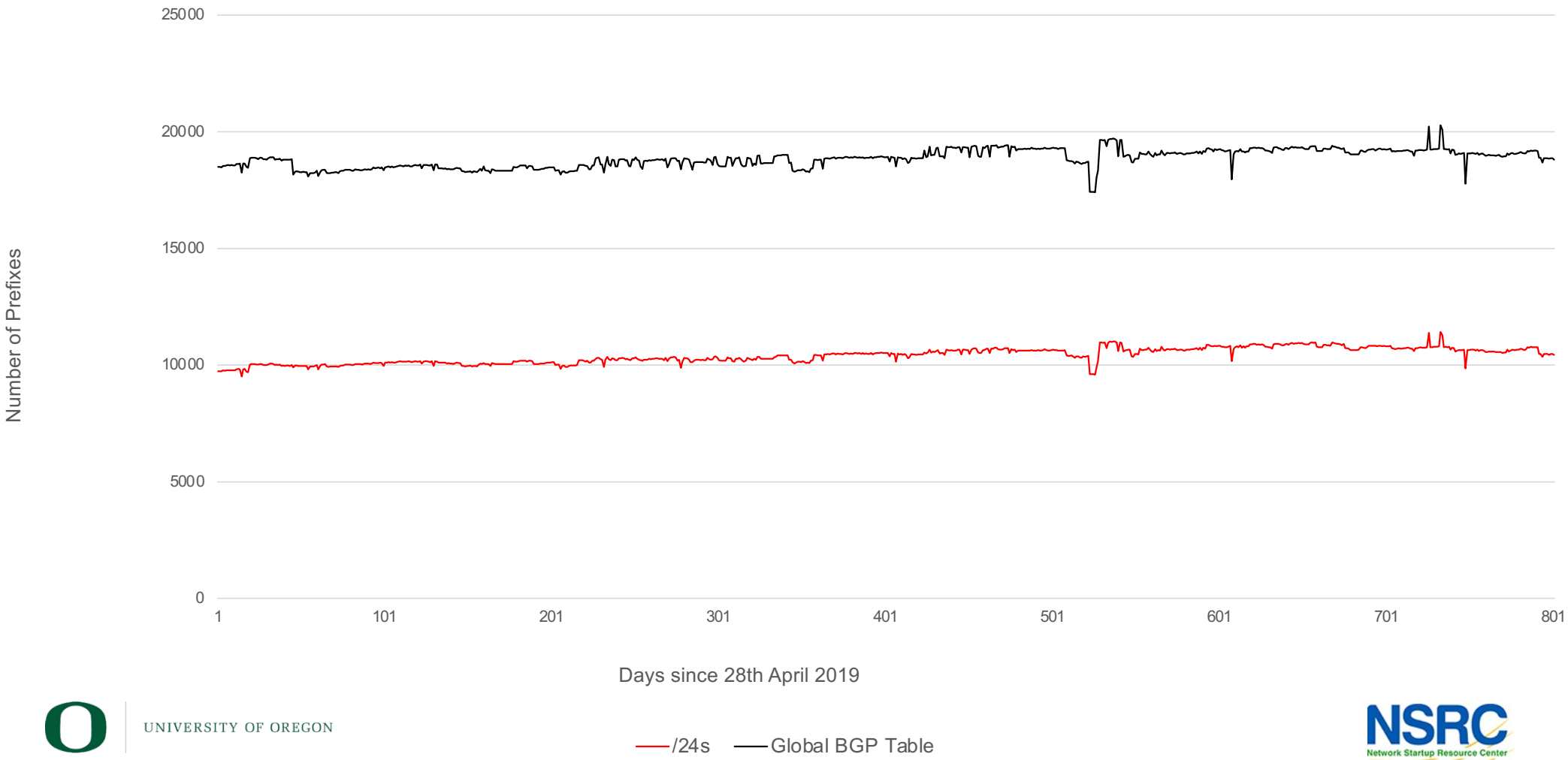
IPv4 /24s announced



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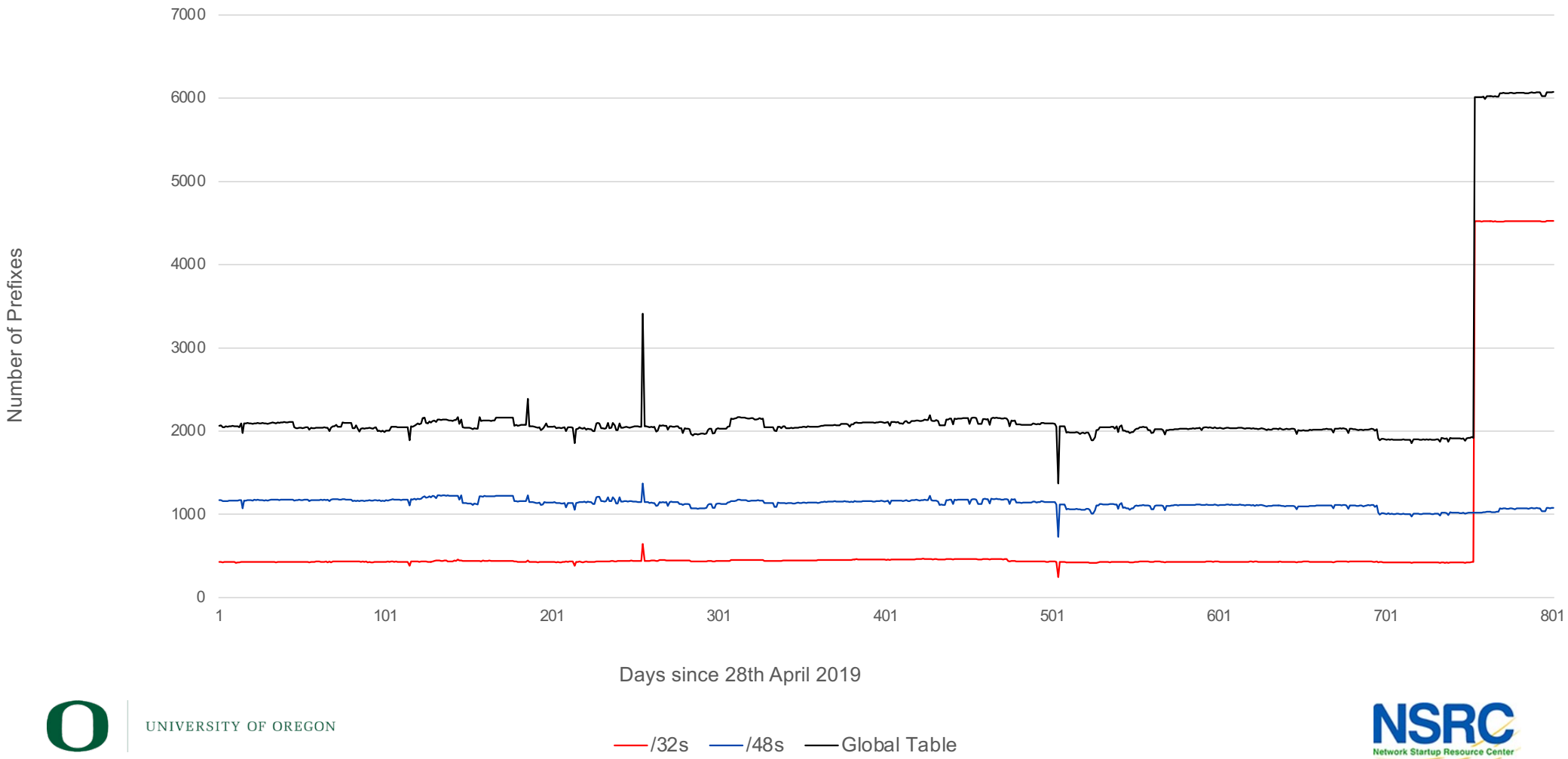
IPv6 /32s vs /48s announced



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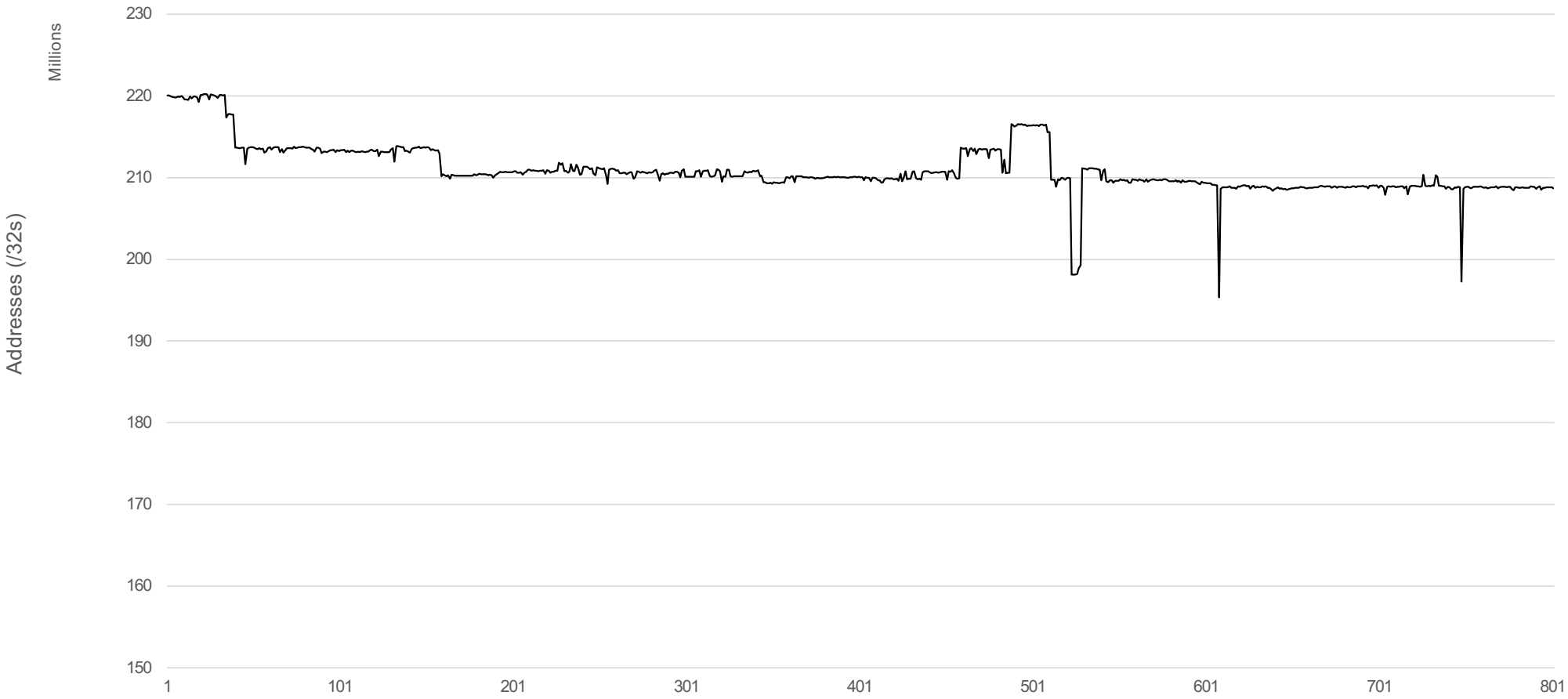
IPv4 Address Space announced



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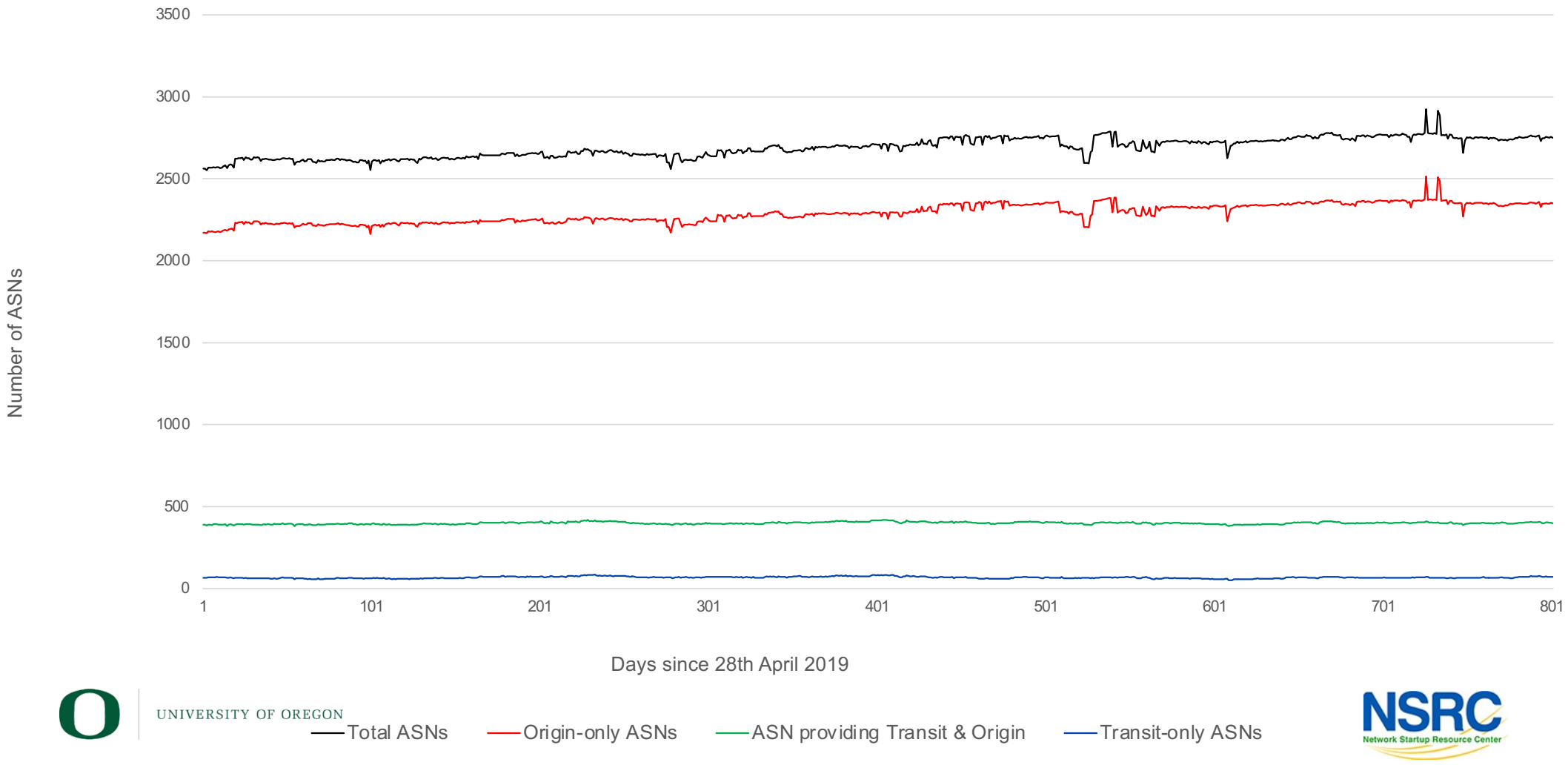
IPv4 AS Announcements



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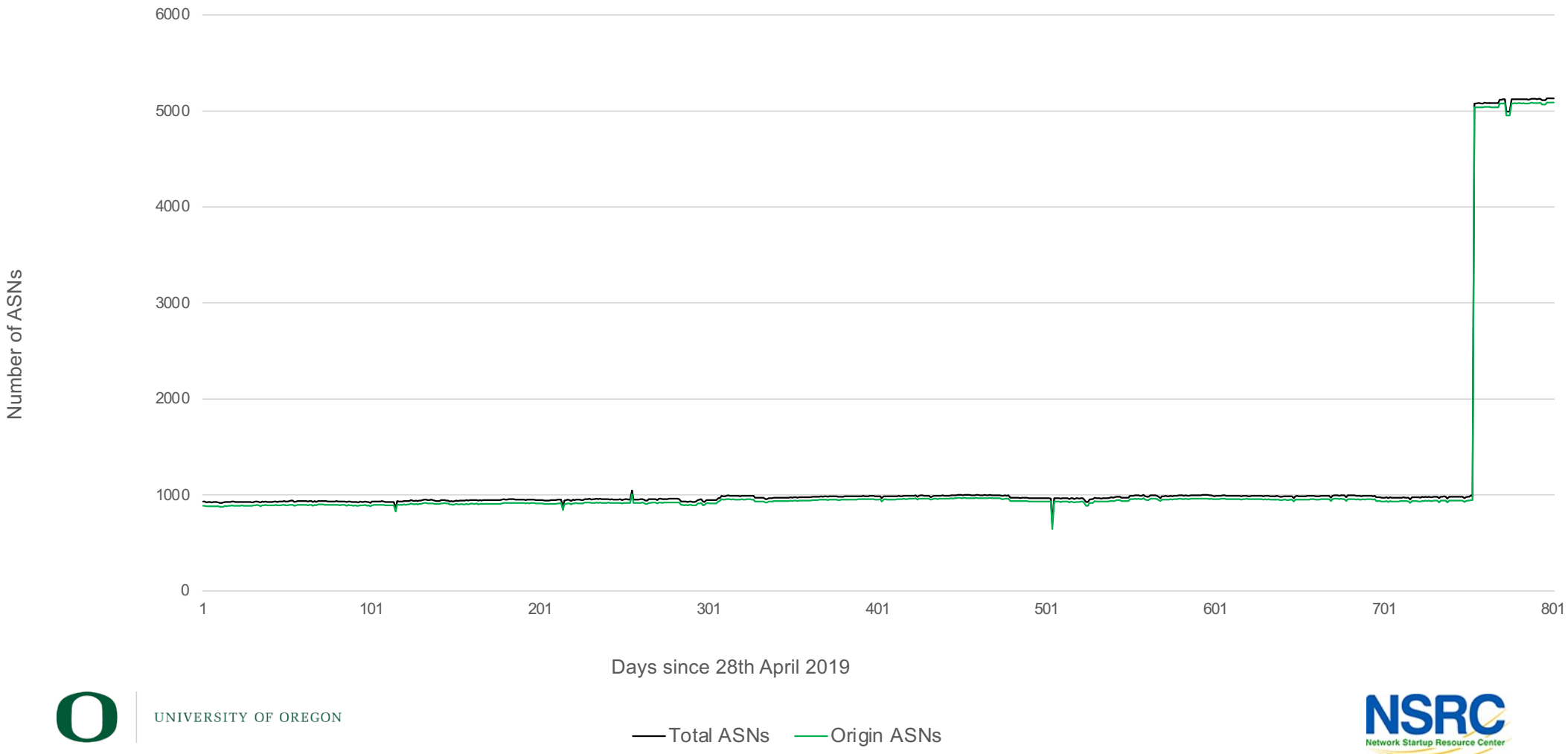
IPv6 AS Announcements



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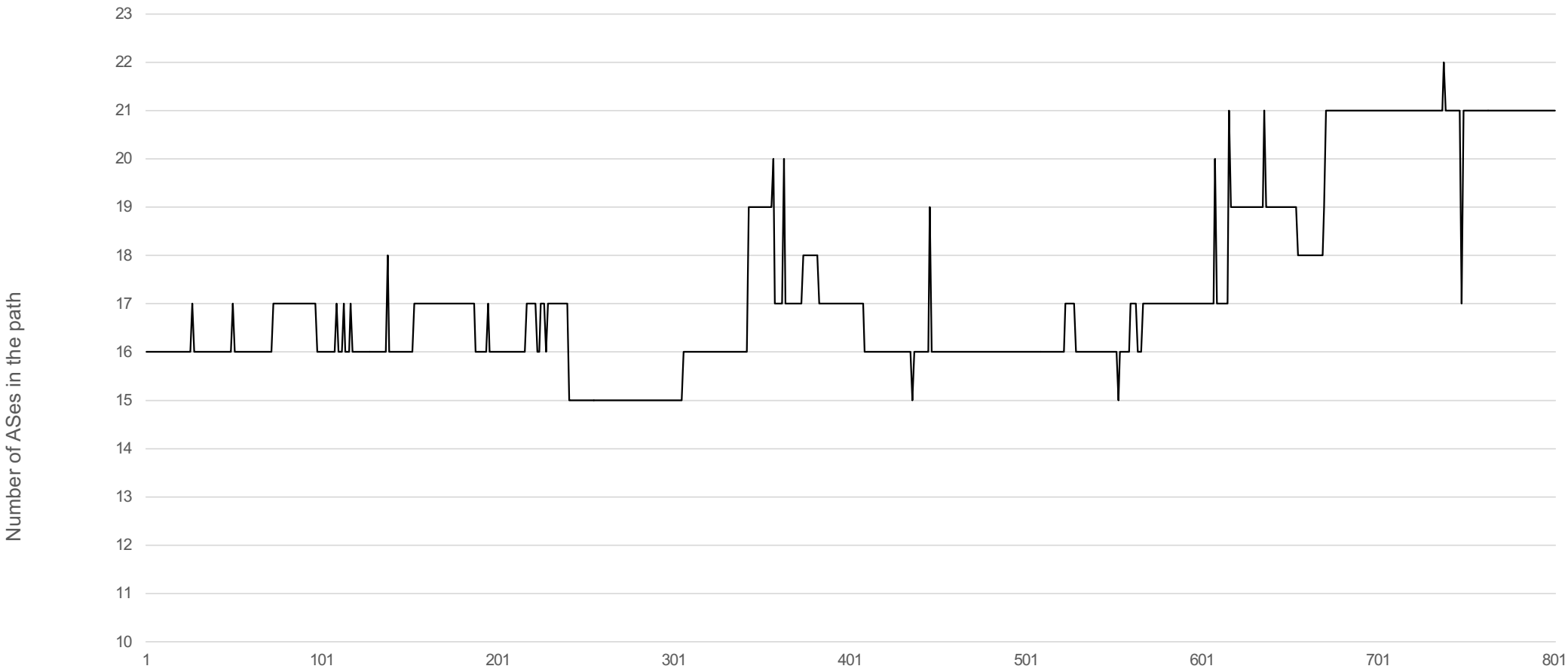
IPv4 Maximum AS Path Length



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Big prepends

- What is the World Bank hoping to achieve?

```
*> 192.86.100.0/24        134715 9885 11537 4901 10497 10497 10497 10497 10497 10497 10497 10497 10497
10497 10497 i
```

- AS10497 gets transit from AS209 and AS6461
  - https://bgp.he.net/AS10497#_graph4
  - Yet the only path R&E networks see is via AS4901 (CAAREN)
- Routeviews shows:

```
 20912 3257 3356 209 10497
  1221 4637 3356 209 10497
  3267 2603 11537 4901 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497
  3333 1273 3356 209 10497
<snip>
  101 11537 4901 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497
  3277 3267 2603 11537 4901 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497
  7660 22388 11537 4901 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497 10497
<snip>
```

Looking at Deaggregation

- CIDR Report
  - 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

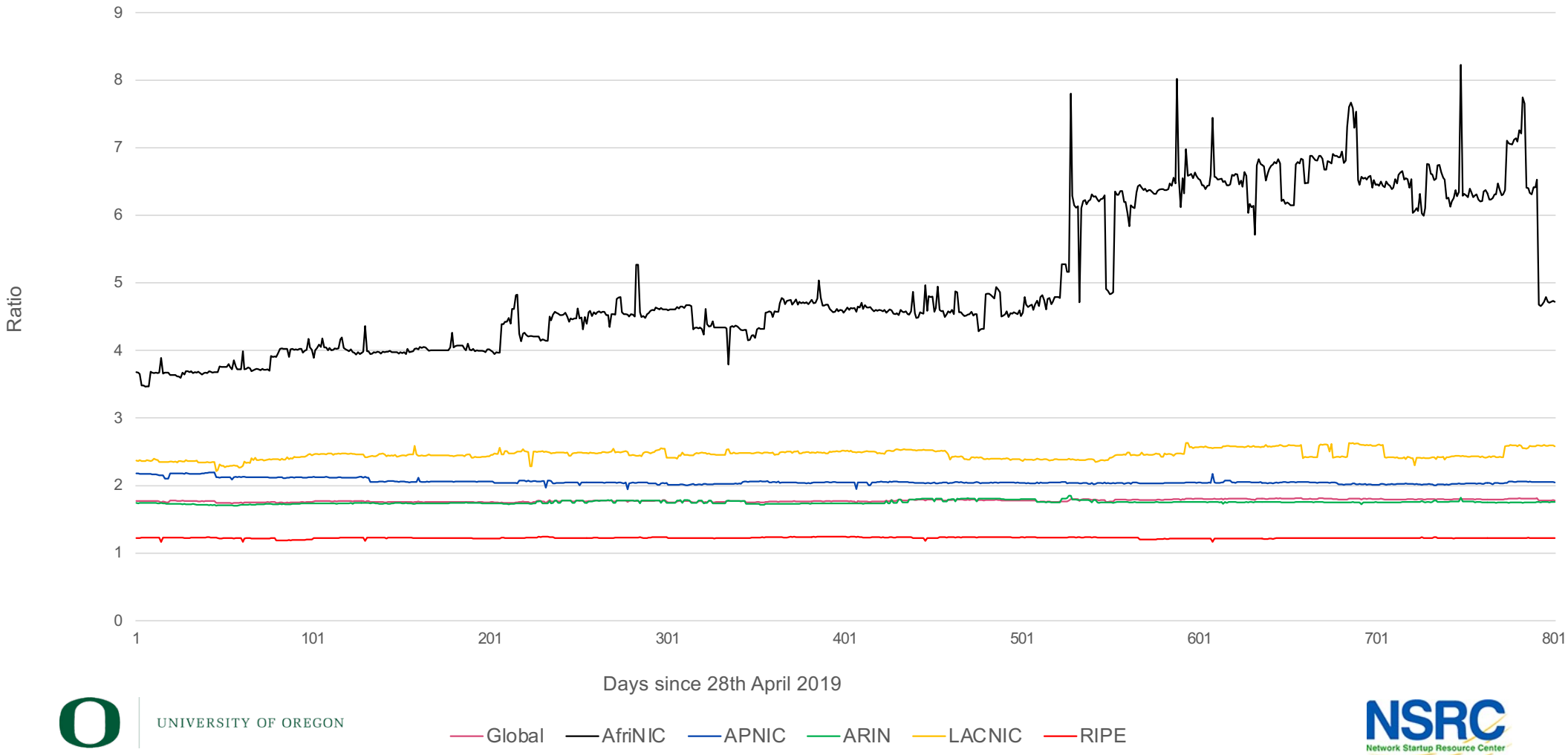
- Routing Report
  - One summary takes BGP table and aggregates prefixes by origin AS
    - Called “Max Aggregation” in report
  - Global R&E and per RIR basis
    - https://bgp.nsrc.org/REN/DrukREN/
- Calculates Deaggregation Factor:
  - Measure of Routing Table size/Aggregated Size
  - Global value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

July 2021

- Total Prefixes
- Global R&E BGP Table
  - 18.8k prefixes
- North America
  - 8.3k prefixes
- Europe & Middle East
  - 3.4k prefixes
- Asia & Pacific
  - 4.7k prefixes
- Latin America & Caribbean
  - 1.5k prefixes
- Africa
  - 0.9k prefixes

- Deaggregation Factor
- Global Average
  - 1.78
- North America
  - 1.76
- Europe & Middle East
  - 1.22
- Asia & Pacific
  - 2.04
- Latin America & Caribbean
  - 2.58
- Africa
  - 4.72

IPv4 Deaggregation: RIR Regions vs Global



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AfriNIC Deaggregation

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

26th 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

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Global IPv4 Aggregation Savings Summary

ASN	No of Nets	Savings	Description
7497	434	405	CSTNET-AS-AP Computer Network Information Cente
2018	324	250	TENET-1, ZA
7896	245	238	NU-AS, US
5786	201	200	UPRENET, PR
58647	164	162	KAGAWAU-AS Kagawa University, JP
4758	156	155	NICNET-VSNL-BOARDER-AP National Informatics Cen
1916	178	137	Associacao Rede Nacional de Ensino e Pesquisa,
8895	141	137	ISU Internet Services Unit ISU, SA
18558	137	133	NETBLK-RCOEK, US
327687	136	133	RENU, UG
55824	131	106	NKN-CORE-NW NKN Core Network, IN
2920	109	103	LACOE, US
23024	114	97	OCDE, US
36914	99	96	KENET-AS, KE
27884	97	95	CABLECOLOR S.A., HN
28391	152	86	Universidad Juarez Autonoma de Tabasco, MX
1736	80	79	MU-AS, US
376	235	77	RISQ-AS, CA
4621	81	71	UNINET-AS-AP UNINET-, TH
2152	159	68	CSUNET-NW, US

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

IPv4 Observations

- Routing table is quite stable
  - Little growth, in fact 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

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 20th this year:
    - CERNET announcement of 4096 /32s from 4096 ASNs
  - In contrast, global table (commodity) is growing quickly

Global R&E Routing Table Update

Questions?