



Internet Routing Table Analysis Update

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SANOG 33

9th January 2019

Thimphu, Bhutan



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
- With support of APNIC, my weekly reporting report started 23rd February 1999:
 - Routing table size
 - CIDR-Report style reporting on a per-RIR basis
 - ...and many other interesting features
- Started recording global IPv6 table in September 2010

IPv4 Routing Report 7th January 2019

BGP routing table entries examined:	733350
Prefixes after maximum aggregation (per Origin AS):	281548
Deaggregation factor:	2.60
Unique aggregates announced (without unneeded subnets):	352778
Total ASes present in the Internet Routing Table:	62823
Prefixes per ASN:	11.67
Origin-only ASes present in the Internet Routing Table:	54146
Origin ASes announcing only one prefix:	23528
Transit ASes present in the Internet Routing Table:	8677
Transit-only ASes present in the Internet Routing Table:	266
Average AS path length visible in the Internet Routing Table:	4.2
Max AS path length visible:	31
Max AS path prepend of ASN (16327)	25
Prefixes from unregistered ASNs in the Routing Table:	22
Number of instances of unregistered ASNs:	24
Number of 32-bit ASNs allocated by the RIRs:	25387
Number of 32-bit ASNs visible in the Routing Table:	20566
Prefixes from 32-bit ASNs in the Routing Table:	88631
Number of bogon 32-bit ASNs visible in the Routing Table:	17
Special use prefixes present in the Routing Table:	1
Prefixes being announced from unallocated address space:	263
Number of addresses announced to Internet:	2841019105
Equivalent to 169 /8s, 86 /16s and 130 /24s	
Percentage of available address space announced:	76.7
Percentage of allocated address space announced:	76.7
Percentage of available address space allocated:	100.0
Percentage of address space in use by end-sites:	99.1
Total number of prefixes smaller than registry allocations:	245019

APNIC Region

Prefixed being announced by APNIC Region ASes:	200425
Total APNIC prefixes after maximum aggregation:	56899
APNIC Deaggregation factor:	3.52
Prefixed being announced from the APNIC address blocks:	197550
Unique aggregates announced from the APNIC address blocks:	81250
APNIC Region origin ASes present in the Internet Routing Table:	9339
APNIC Prefixes per ASN:	21.15
APNIC Region origin ASes announcing only one prefix:	2643
APNIC Region transit ASes present in the Internet Routing Table:	1394
Average APNIC Region AS path length visible:	4.1
Max APNIC Region AS path length visible:	26
Number of APNIC region 32-bit ASNs visible in the Routing Table:	4333
Number of APNIC addresses announced to Internet:	769249792
Equivalent to 45 /8s, 217 /16s and 210 /24s	

APNIC AS Blocks	4608-4864, 7467-7722, 9216-10239, 17408-18431
(pre-ERX allocations)	23552-24575, 37888-38911, 45056-46079, 55296-56319, 58368-59391, 63488-64098, 64297-64395, 131072-139577

APNIC Address Blocks	1/8, 14/8, 27/8, 36/8, 39/8, 42/8, 43/8, 49/8, 58/8 to 61/8, 101/8, 103/8, 106/8, 110/8 to 126/8, 133/8, 175/8, 180/8, 182/8, 183/8, 202/8, 203/8, 210/8, 211/8, 218/8 to 223/8
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Global per AS prefix count summary

ASN	No of nets /20	equiv	Max Agg	Description
8151	5465	3319	588	Uninet S.A. de C.V., MX
12479	5262	1628	138	UNI2-AS, ES
7545	4656	515	521	TPG-INTERNET-AP TPG Telecom Limited, AU
4538	4644	4192	74	ERX-CERNET-BKB China Education and Rese
39891	3778	203	20	ALJAWWALSTC-AS, SA
6327	3503	1326	92	SHAW - Shaw Communications Inc., CA
11492	3485	225	601	CABLEONE - CABLE ONE, INC., US
22773	3309	2979	174	ASN-CXA-ALL-CCI-22773-RDC - Cox Communi
8551	3290	378	43	BEZEQ-INTERNATIONAL-AS Bezeqint Interne
10620	3150	475	905	Telmex Colombia S.A., CO
7552	3017	1160	90	VIETEL-AS-AP Viettel Group, VN
45899	2986	1717	115	VNPT-AS-VN VNPT Corp, VN
4766	2813	11129	767	KIXS-AS-KR Korea Telecom, KR
9829	2749	1496	551	BSNL-NIB National Internet Backbone, IN
11830	2679	371	71	Instituto Costarricense de Electricidad
20940	2629	574	1931	AKAMAI-ASN1, US
16509	2599	5292	976	AMAZON-02 - Amazon.com, Inc., US
9808	2500	8699	26	CMNET-GD Guangdong Mobile Communication
9394	2408	4906	29	CTTNET China TieTong Telecommunications
17974	2253	968	50	TELKOMNET-AS2-AP PT Telekomunikasi Indo

AfrINIC APNIC ARIN LACNIC RIPE NCC

List of Unregistered Origin ASNs (Global)

Bogon AS	Designation	Network	Transit AS	Description
230105	UNALLOCATED	38.110.79.0/24	23015	CMC180-TOR-AS - Cambridge Merc
266842	UNALLOCATED	45.238.156.0/22	265680	HNTTELCO S.A, HN
4200058511	PRIVATE	103.111.177.0/24	137522	OERL-AS-AP Origin Energy Retai
4200058511	PRIVATE	103.111.178.0/24	137522	OERL-AS-AP Origin Energy Retai
64339	UNALLOCATED	143.0.108.0/22	18747	IFX18747 - IFX Corporation, US
64355	UNALLOCATED	156.40.196.0/24	30387	NIH-NET-NCCS - National Instit
64011	UNALLOCATED	166.133.128.0/18	20057	ATT-MOBILITY-LLC-AS20057 - AT&
64011	UNALLOCATED	166.133.192.0/18	20057	ATT-MOBILITY-LLC-AS20057 - AT&
64011	UNALLOCATED	166.184.9.0/24	20057	ATT-MOBILITY-LLC-AS20057 - AT&
64011	UNALLOCATED	166.220.64.0/19	20057	ATT-MOBILITY-LLC-AS20057 - AT&
64011	UNALLOCATED	166.220.96.0/19	20057	ATT-MOBILITY-LLC-AS20057 - AT&
64141	UNALLOCATED	181.119.152.0/24	64044	EP2-AS-AP EP2 Payments Pty Ltd
65540	DOCUMENT	185.168.163.0/24	3257	GTT-BACKBONE GTT, DE
65537	DOCUMENT	189.206.63.0/24	11172	Alestra, S. de R.L. de C.V., M
65610	UNALLOCATED	192.96.139.0/24	11845	Vox-Telecom, ZA
64042	UNALLOCATED	192.104.151.0/24	7018	ATT-INTERNET4 - AT&T Services,
327074	UNALLOCATED	196.216.227.0/24	36974	AFNET-AS, CI
64506	DOCUMENT	198.55.226.0/23	14495	ASN-14495 - Nasdaq, Inc., US
65543	DOCUMENT	199.223.120.0/24	65537	UNKNOWN
65817	UNALLOCATED	202.75.201.0/24	703	UUNET - MCI Communications Ser
64510	DOCUMENT	216.52.28.0/24	12182	INTERNAP-2BLK - Internap Corpo
64510	DOCUMENT	216.52.29.0/24	12182	INTERNAP-2BLK - Internap Corpo

Number of prefixes announced by prefix length

/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:15
/9:12	/10:37	/11:99	/12:279	/13:558	/14:1089	/15:1895	/16:13407
/17:7769	/18:13677	/19:25266	/20:38888	/21:44679	/22:82869	/23:66685	/24:378629
/25:844	/26:608	/27:655	/28:36	/29:20	/30:17	/31:4	/32:60

7th January 2018 ↑

7th January 2019 ↓

/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:12
/9:10	/10:36	/11:99	/12:293	/13:568	/14:1127	/15:1913	/16:13342
/17:7877	/18:13852	/19:25515	/20:39694	/21:46177	/22:91304	/23:74679	/24:413972
/25:924	/26:822	/27:882	/28:32	/29:18	/30:9	/31:2	/32:191



What about IPv6 ?

Table Size	58812
Number of /32s	11272
Number of /48s	27281
Number of prefixes >/48	0 ← ISP is Filtering 😊
Number of prefixes >/32 and </48	17298
Number of prefixes >/16 and </32	2946

Number of IPv6 prefixes announced by prefix length

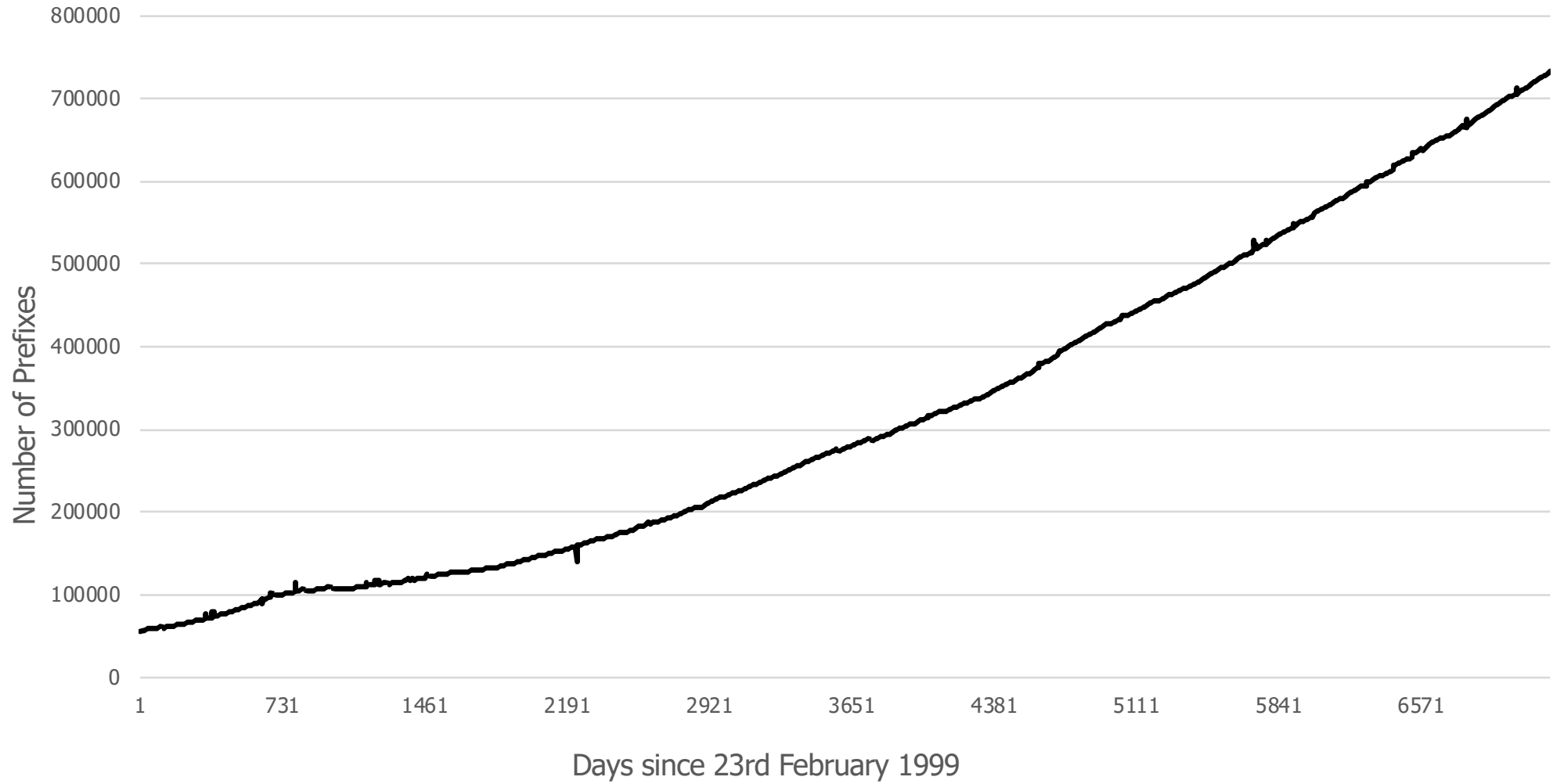
/16:0	/17:0	/18:0	/19:2	/20:13	/21:4	/22:6	/23:4
/24:2	/25:6	/26:13	/27:17	/28:87	/29:2424	/30:226	/31:124
/32:11272	/33:779	/34:630	/35:431	/36:2472	/37:445	/38:799	/39:267
/40:3299	/41:438	/42:692	/43:133	/44:4251	/45:377	/46:1595	/47:690
/48:27281	/49 → /128: FILTERED by ISP						

7th January 2019 ↑

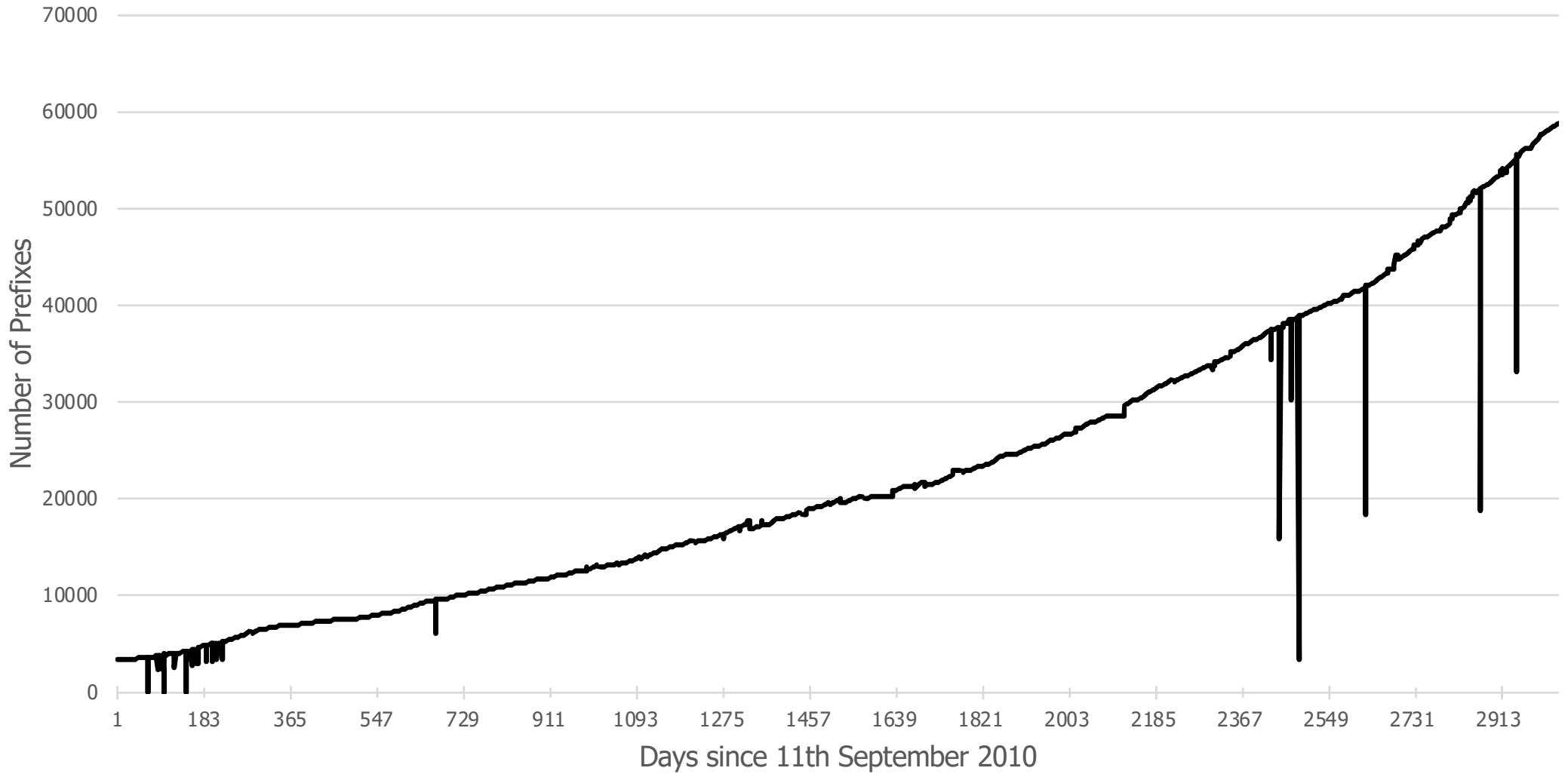
7th January 2011 ↓

/16:1	/17:0	/18:0	/19:2	/20:5	/21:4	/22:4	/23:1
/24:2	/25:1	/26:5	/27:5	/28:11	/29:4	/30:8	/31:5
/32:2409	/33:47	/34:27	/35:54	/36:94	/37:2	/38:8	/39:2
/40:108	/41:6	/42:27	/43:3	/44:29	/45:7	/46:13	/47:21
/48:1122	/49 → /128: FILTERED by ISP						

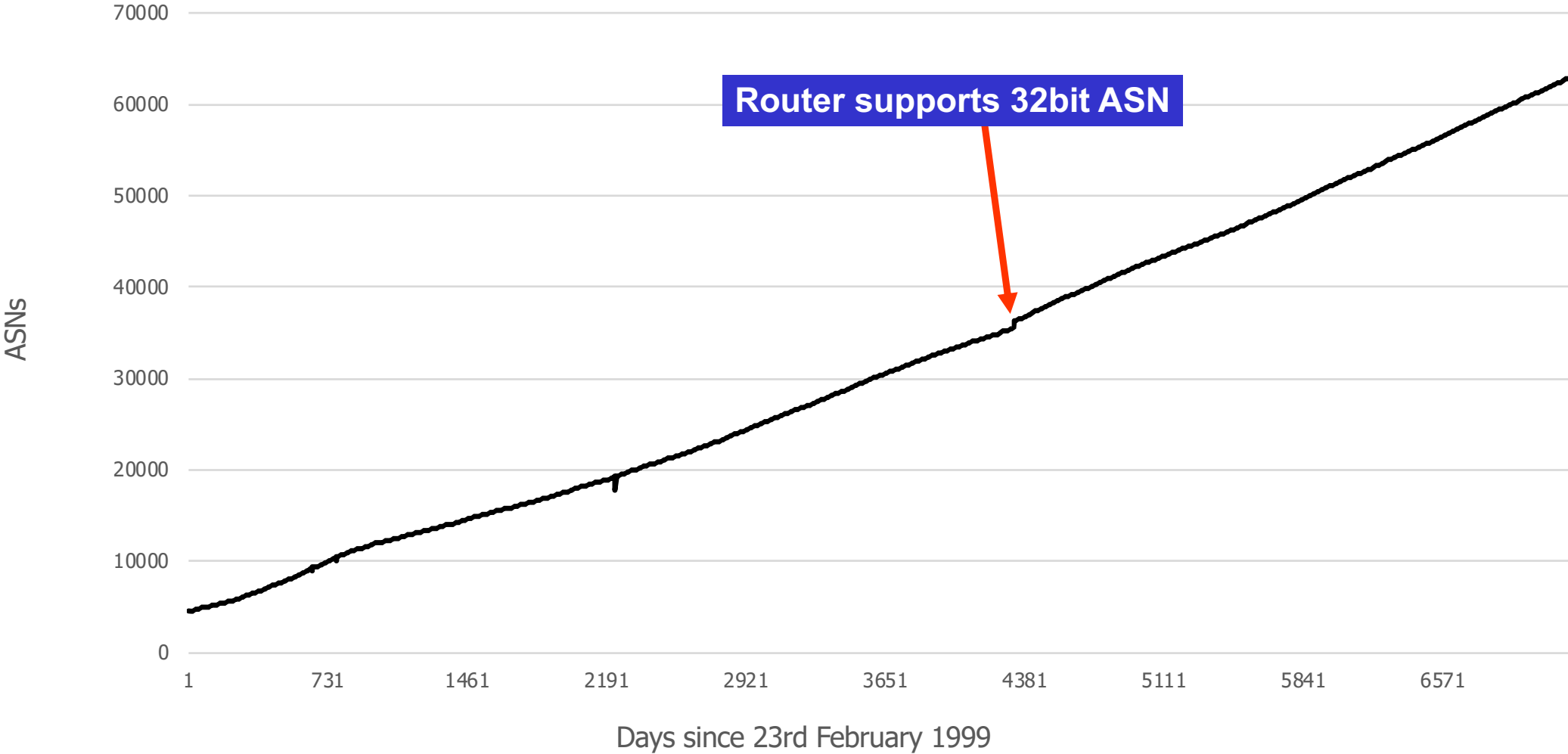
Global IPv4 Routing Table



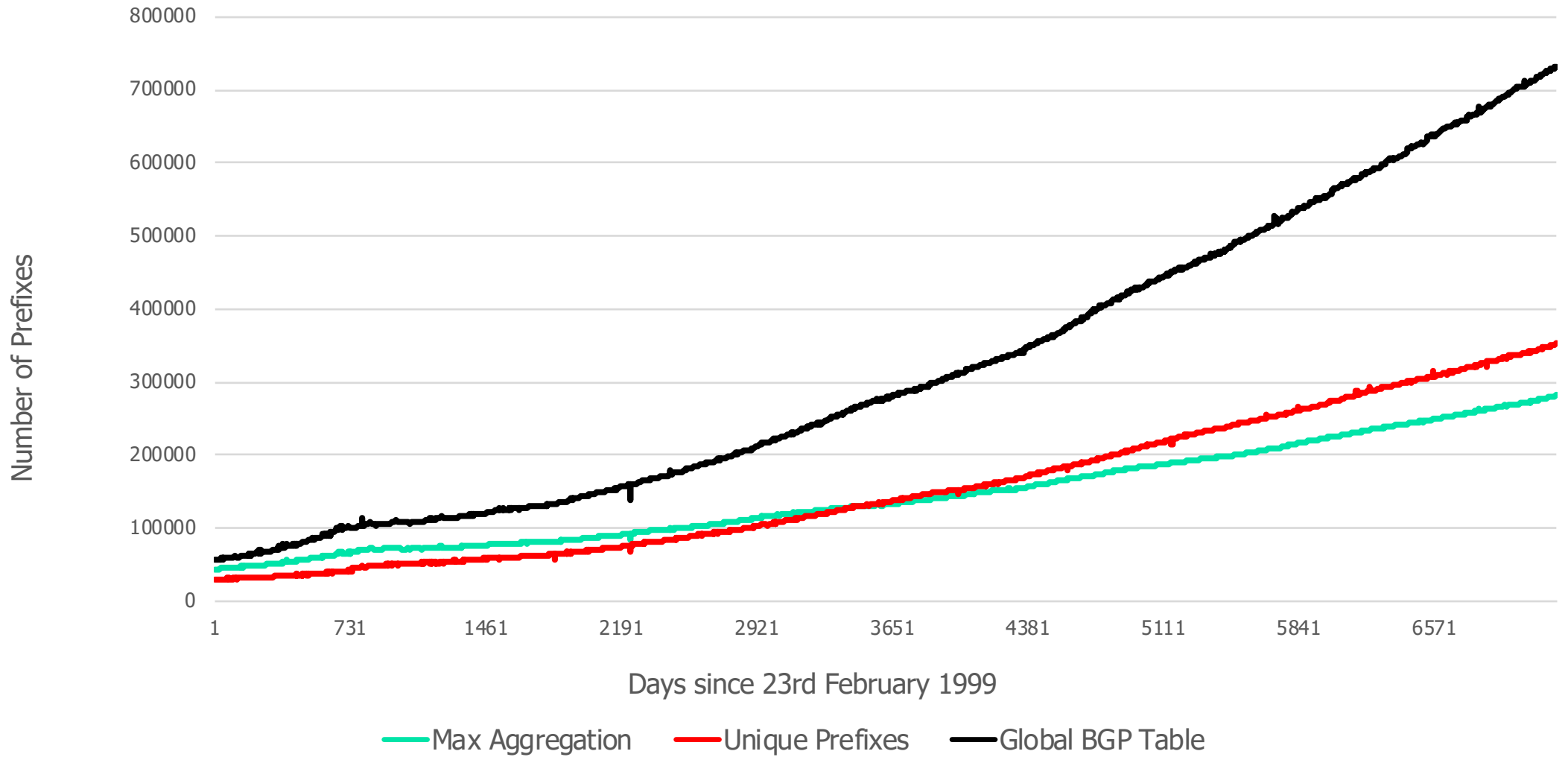
Global IPv6 Routing Table



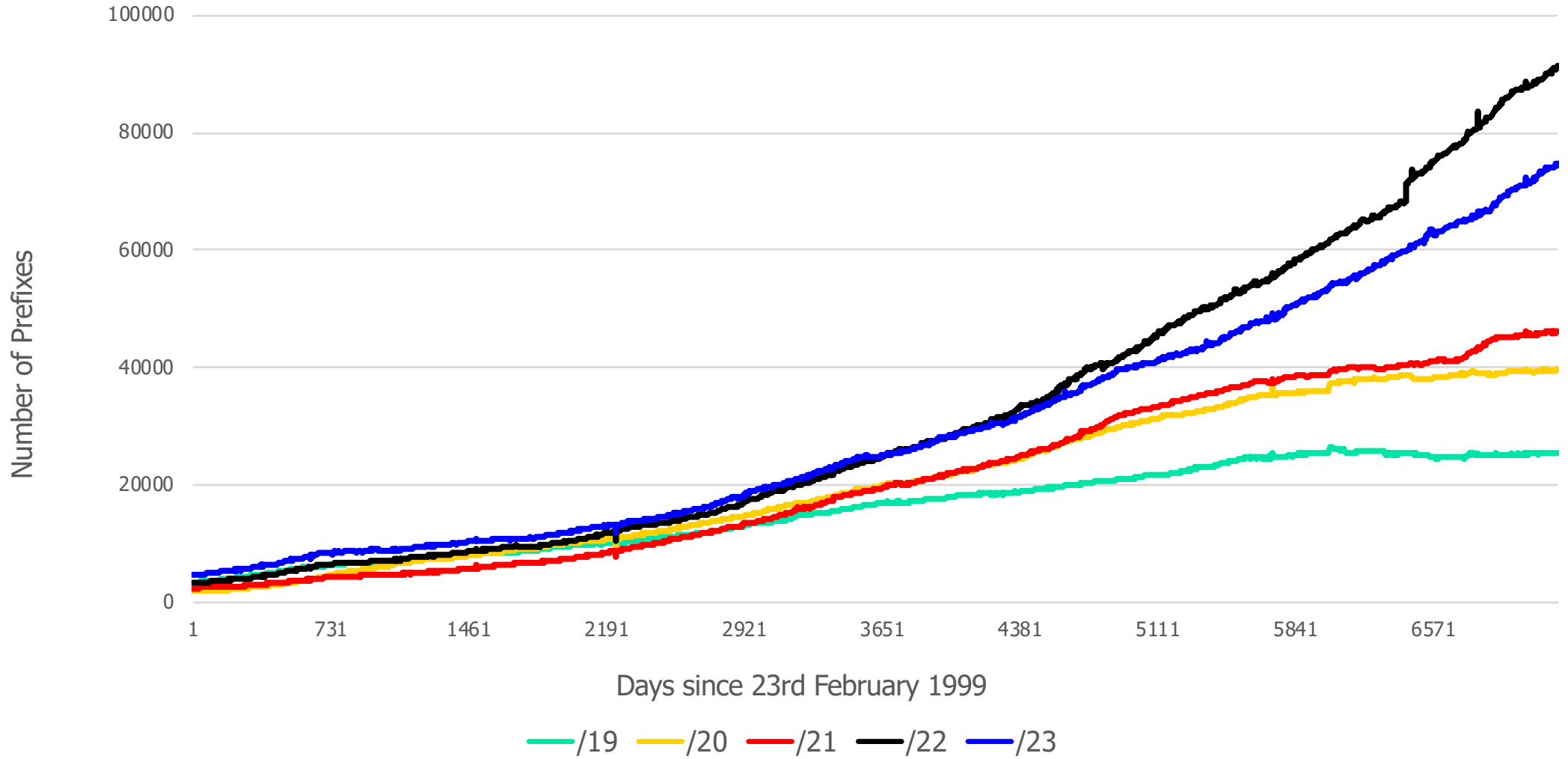
AS Growth



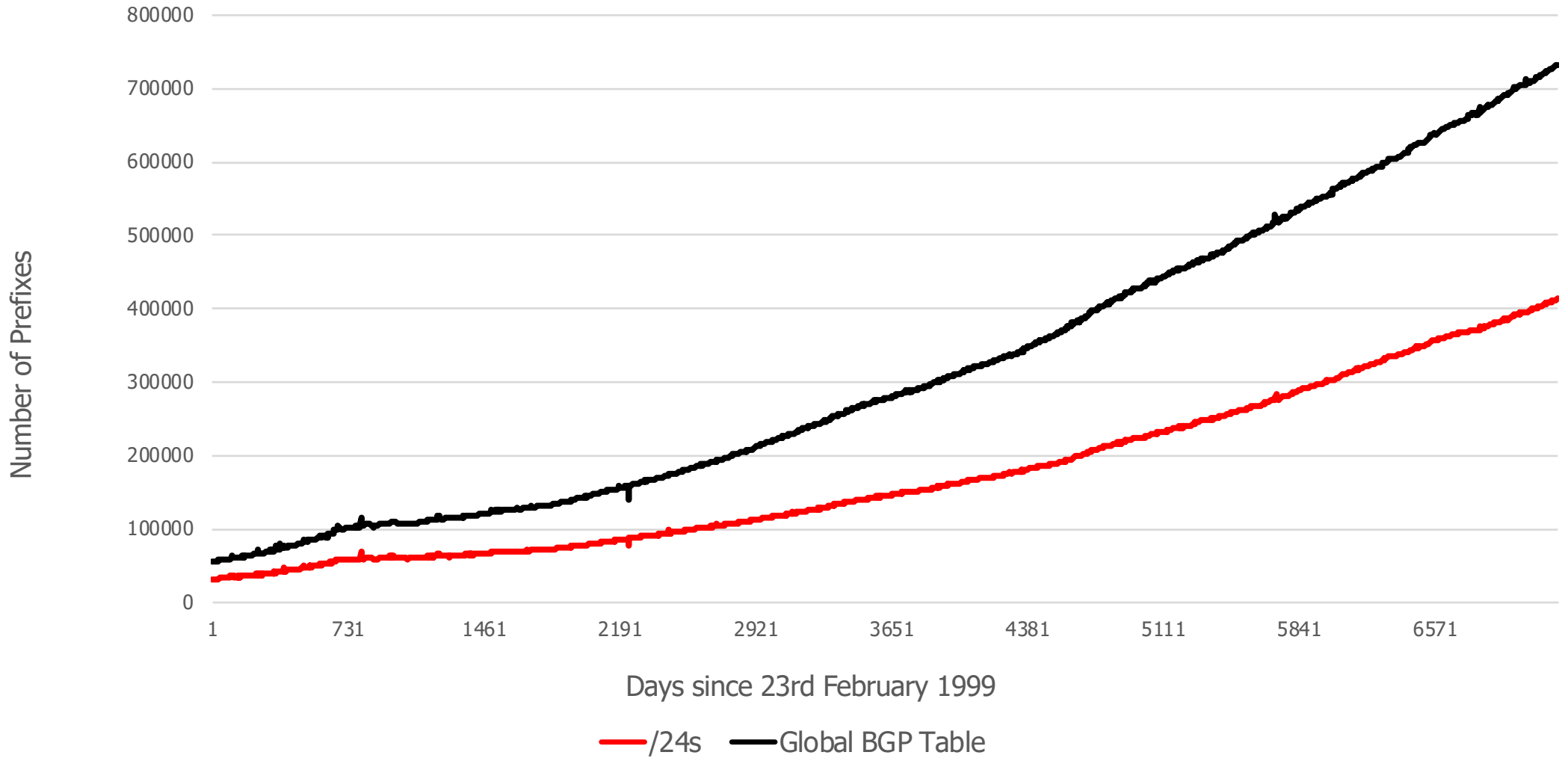
Max Aggregation vs Unique Prefixes



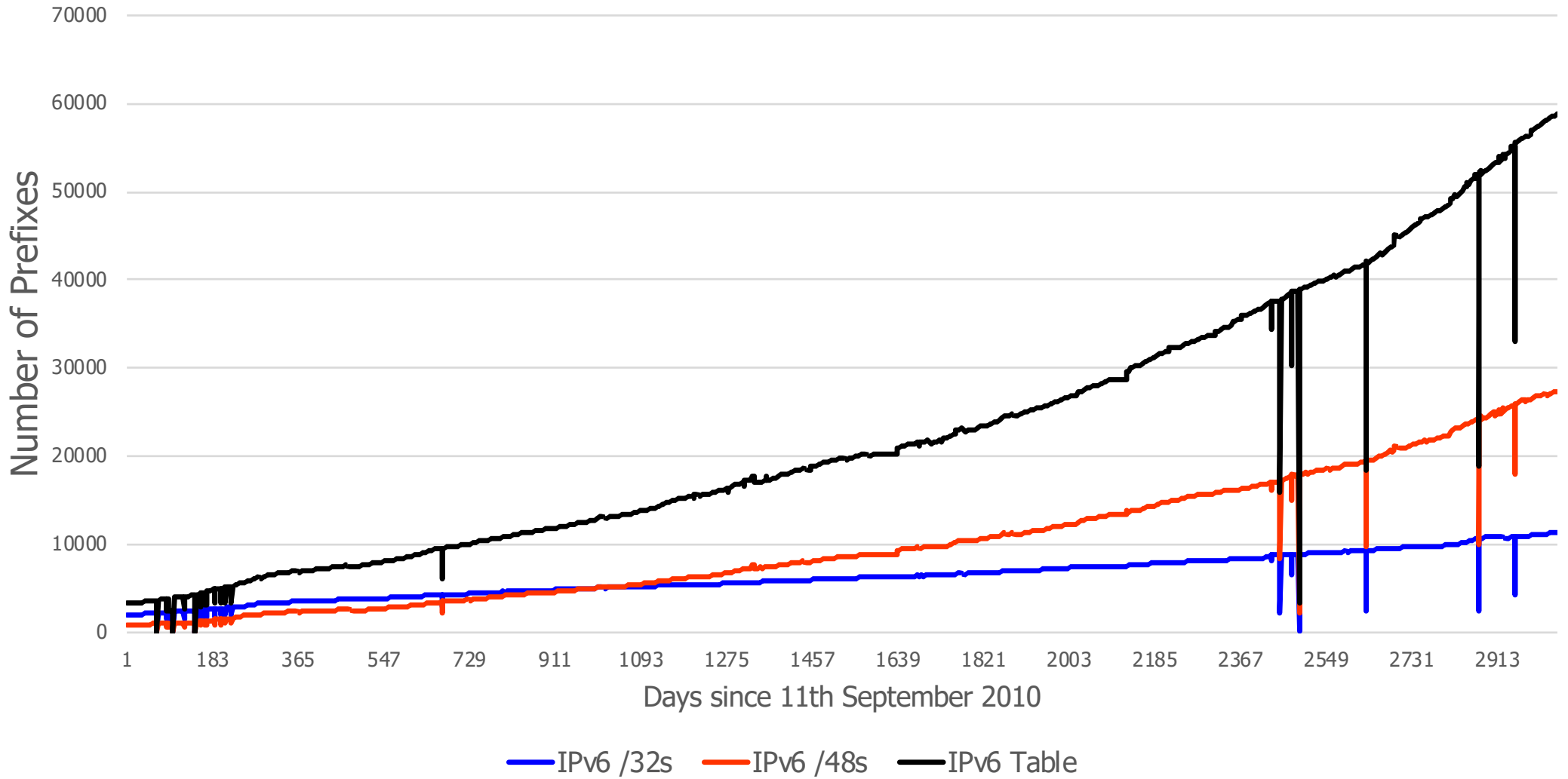
Prefix sizes announced



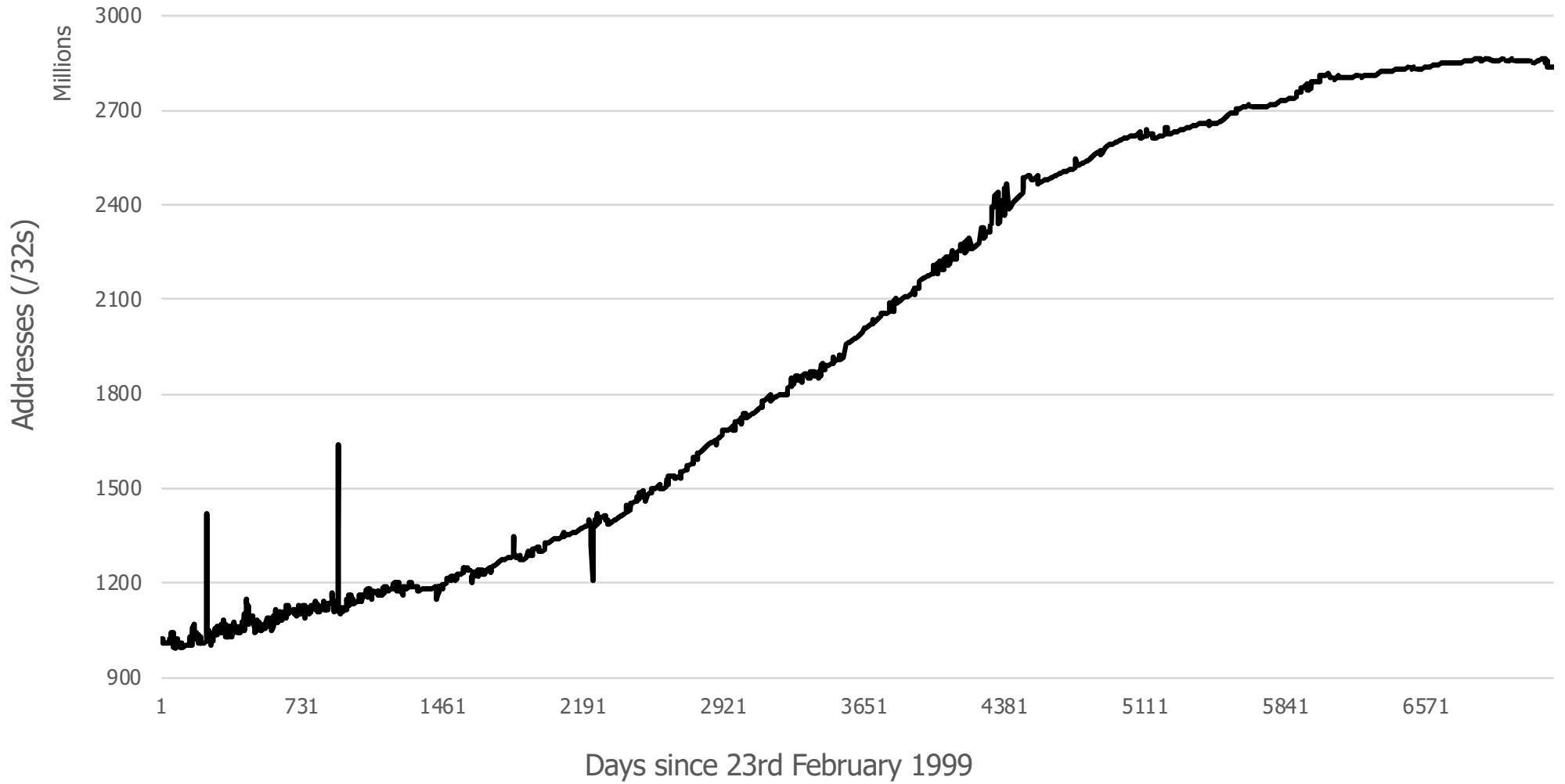
/24s announced



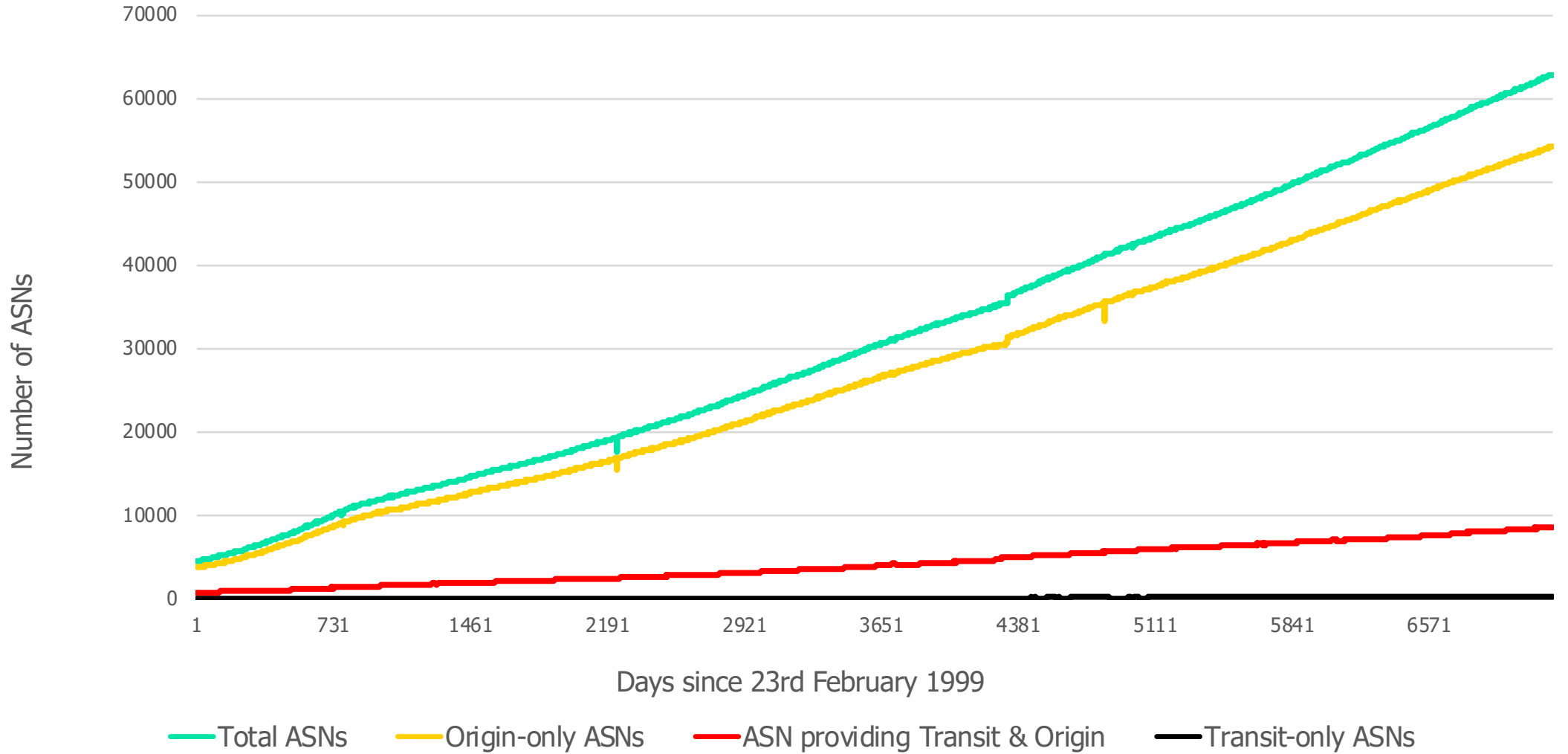
IPv6 /32s vs /48s



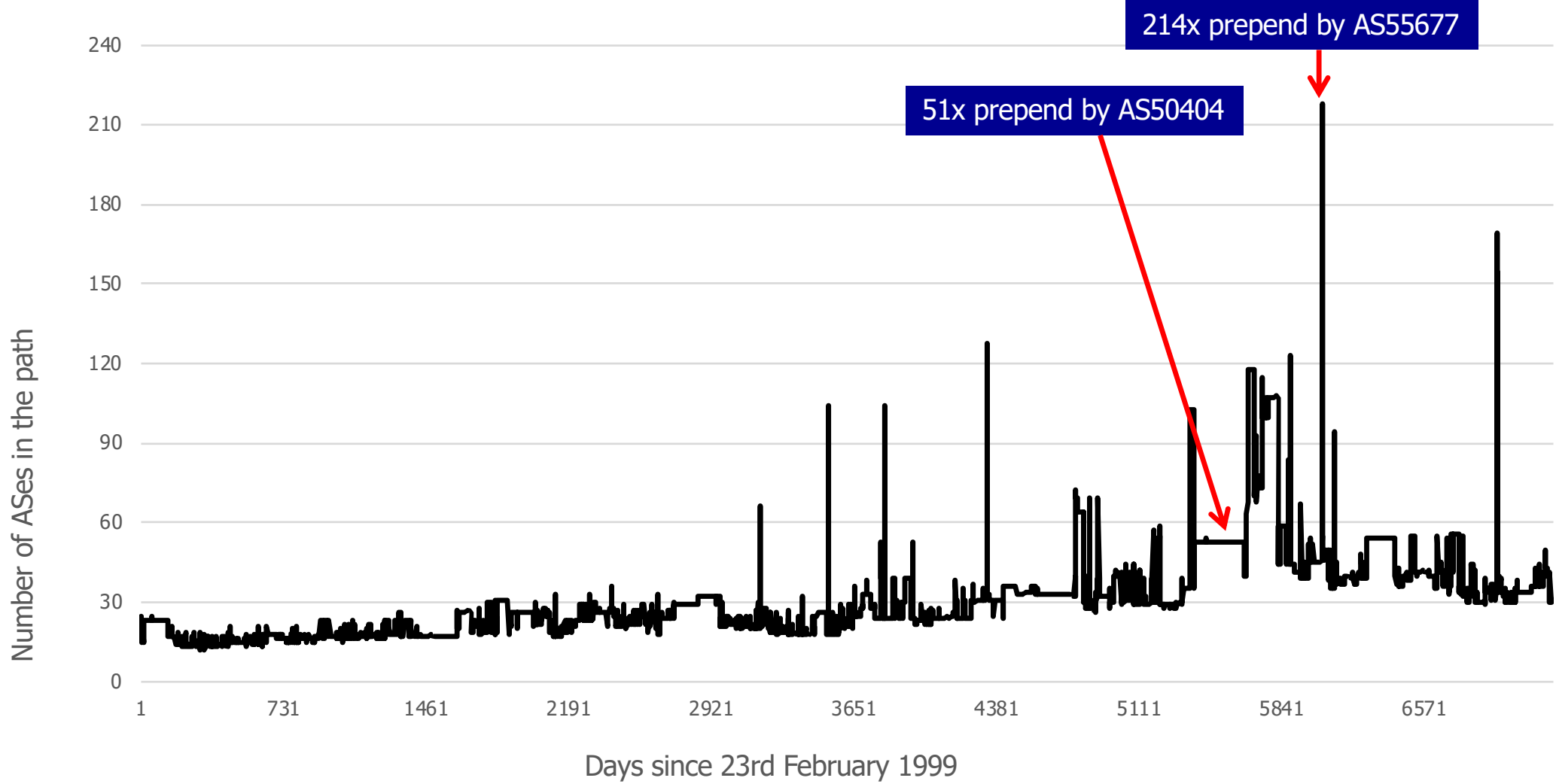
IPv4 Address Space announced



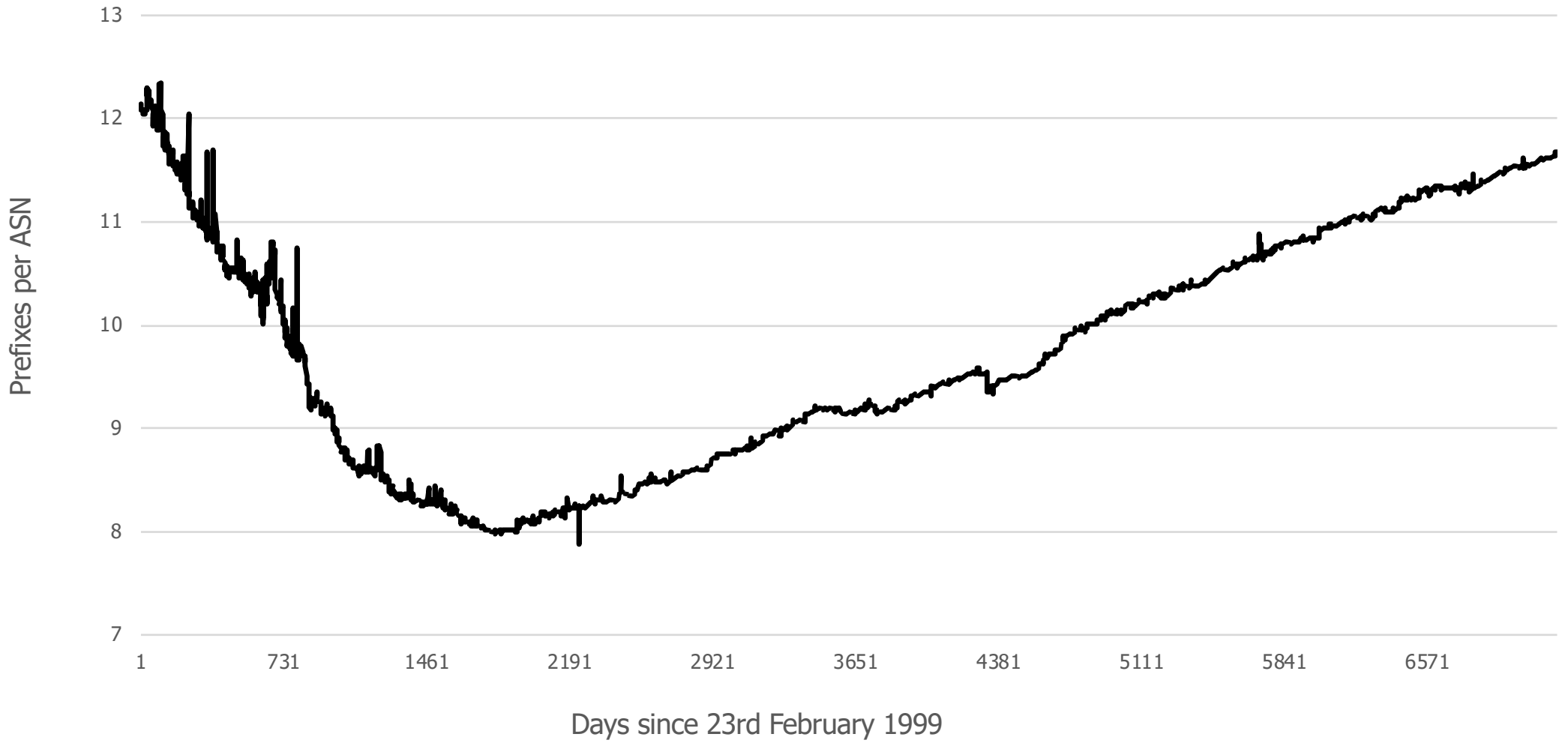
AS Announcements



Maximum AS Path Length



Prefixes per ASN





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

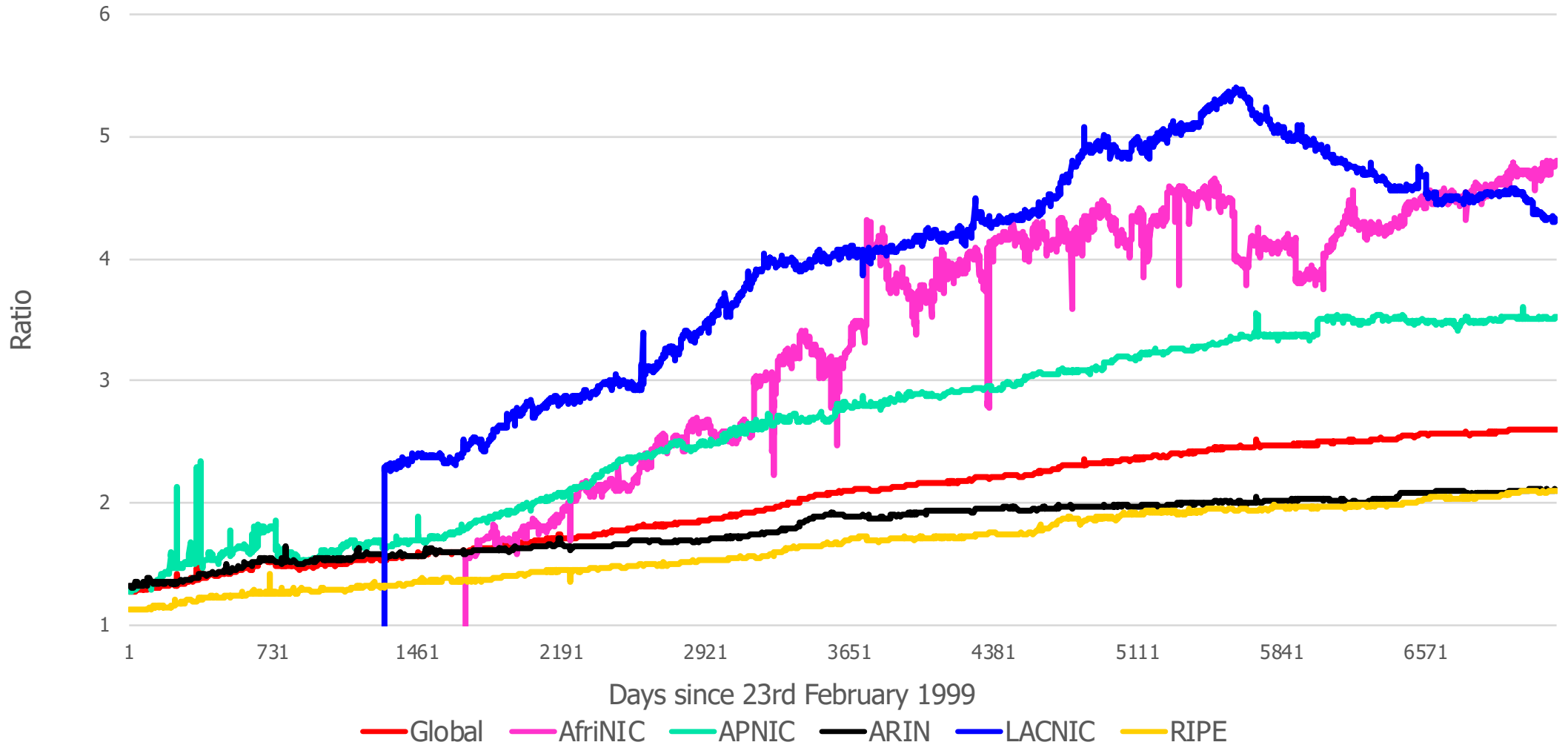
- Routing Report
 - One summary takes BGP table and aggregates prefixes by origin AS
 - Called “Max Aggregation” in report
 - Global and per RIR basis
 - <http://thyme.apnic.net/current/>
- Calculates **Deaggregation** Factor:
 - Measure of Routing Table size/Aggregated Size
 - Global value has been increasing slowly and steadily since “records began”



January 2019

- **Total Prefixes**
- Global BGP Table
 - 733k prefixes
- North America
 - 217k prefixes
- Europe & Middle East
 - 201k prefixes
- Asia & Pacific
 - 200k prefixes
- Latin America & Caribbean
 - 95k prefixes
- Africa
 - 20k prefixes
- **Deaggregation Factor**
- Global Average
 - 2.60
- North America
 - 2.11
- Europe & Middle East
 - 2.10
- Asia & Pacific
 - 3.52
- Latin America & Caribbean
 - 4.33
- Africa
 - 4.80

Deaggregation: RIR Regions vs Global



Asia Pacific Aggregation Savings Summary

ASN	No of Nets	Savings	Description
4538	4644	4570	ERX-CERNET-BKB China Education and Research Net
7545	4656	4135	TPG-INTERNET-AP TPG Telecom Limited, AU
7552	3017	2927	VIETEL-AS-AP Viettel Group, VN
45899	2986	2871	VNPT-AS-VN VNPT Corp, VN
9808	2500	2474	CMNET-GD Guangdong Mobile Communication Co.Ltd.
9394	2408	2379	CTTNET China TieTong Telecommunications Corpora
17974	2253	2203	TELKOMNET-AS2-AP PT Telekomunikasi Indonesia, I
9829	2749	2198	BSNL-NIB National Internet Backbone, IN
4766	2813	2046	KIXS-AS-KR Korea Telecom, KR
4755	2141	1960	TATACOMM-AS TATA Communications formerly VSNL i
9498	1955	1799	BBIL-AP BHARTI Airtel Ltd., IN
23969	1762	1746	TOT-NET TOT Public Company Limited, TH
45609	1894	1674	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for
45090	1510	1468	CNNIC-TENCENT-NET-AP Shenzhen Tencent Computer
18403	1342	1313	FPT-AS-AP The Corporation for Financing & Promo
4808	1612	1173	CHINA169-BJ China Unicom Beijing Province Netwo
56040	1200	1148	CMNET-GUANGDONG-AP China Mobile communications
55430	1130	1102	STARHUB-NGNBN Starhub Ltd, SG
9583	1651	1092	SIFY-AS-IN Sify Limited, IN
24560	1303	973	AIRTELBROADBAND-AS-AP Bharti Airtel Ltd., Telem

<http://thyme.apnic.net/current/data-CIDRnet-APNIC>

South Asia Aggregation Savings Summary

ASN	No of Nets	Savings	Description
9829	2749	2198	BSNL-NIB National Internet Backbone, IN
4755	2141	1960	TATACOMM-AS TATA Communications formerly VSNL i
9498	1955	1799	BBIL-AP BHARTI Airtel Ltd., IN
45609	1894	1674	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for
9583	1651	1092	SIFY-AS-IN Sify Limited, IN
24560	1303	973	AIRTELBROADBAND-AS-AP Bharti Airtel Ltd., Telem
18101	959	814	RELIANCE-COMMUNICATIONS-IN Reliance Communicati
132165	861	802	CONNECT-AS-AP Connect Communications, PK
45528	968	779	TIKONAIN-AS Tikona Infinet Ltd., IN
17488	975	774	HATHWAY-NET-AP Hathway IP Over Cable Internet,
45271	699	628	ICLNET-AS-AP Idea Cellular Limited, IN
17439	593	517	NETMAGIC-AP Netmagic Datacenter Mumbai, IN
9541	508	463	CYBERNET-AP Cyber Internet Services (Pvt) Ltd.,
45820	541	455	TTSL-MEISISIP Tata Teleservices ISP AS, IN
10201	504	429	DWL-AS-IN Dishnet Wireless Limited. Broadband W
10029	448	424	SHYAMSPECTRA-AS SHYAM SPECTRA PVT LTD, IN
45595	410	398	PKTELECOM-AS-PK Pakistan Telecom Company Limite
17762	398	368	HTIL-TTML-IN-AP Tata Teleservices Maharashtra L
45769	464	361	DVOIS-IN D-Vois Broadband Pvt Ltd, IN
55410	365	340	VODAFONE-NET-AS-AP C48 Okhla Industrial Estate,



Importance of Aggregation

- Size of routing table
 - Router memory no longer seems to be a problem
 - Routers routinely carry over 1 million prefixes
- Convergence of the Routing System
 - Is this something we need to worry about?
 - Bigger table takes longer for CPU to process
 - BGP updates take longer to deal with
 - BGP Instability Report tracks routing system update activity
 - <http://bgpupdates.potaroo.net/instability/bgpupd.html>

The BGP Instability Report

The BGP Instability Report is updated daily. This report was generated on 07 January 2019 06:54 (UTC+1000)

50 Most active ASes for the past 14 days

RANK	ASN	UPDs	%	Prefixes	UPDs/Prefix	AS NAME
1	4538	1803620	19.96%	4652	387.71	ERX-CERNET-BKB China Education and Research Network Center, CN
2	132165	291860	3.23%	866	337.02	CONNECT-AS-AP Connect Communications, PK
3	9829	163607	1.81%	2749	59.52	BSNL-NIB National Internet Backbone, IN
4	35908	131976	1.46%	836	157.87	VPLSNET - Krypt Technologies, US
5	136743	94435	1.04%	122	774.06	IKTCL-HK Internet Keeper Technology(International) Co., Limited, HK
6	11432	79430	0.88%	120	661.92	Telium Telecomunicações Ltda, BR
7	38527	76685	0.85%	23	3334.13	MLINK-AS-ID JAWA POS NATIONAL NETWORK MEDIALINK, PT, ID
8	134630	64880	0.72%	7	9268.57	PALAPANET-AS-ID PT Palapa Global Nusantara, ID
9	28303	62200	0.69%	56	1110.71	
10	7497	60946	0.67%	685	88.97	CSTNET-AS-AP Computer Network Information Center, CN
11	12389	56371	0.62%	2235	25.22	ROSTELECOM-AS, RU
12	13904	51684	0.57%	151	342.28	COSLINK - Cherryland Services Inc, US
13	23969	50512	0.56%	1778	28.41	TOT-NET TOT Public Company Limited, TH
14	262691	50044	0.55%	139	360.03	CONECTA LTDA., BR
15	21574	47924	0.53%	55	871.35	Century Telecom Ltda, BR
16	7011	44883	0.50%	563	79.72	FRONTIER-AND-CITIZENS - Frontier Communications of America, Inc., US
17	4809	44411	0.49%	220	201.87	CHINATELECOM-CORE-WAN-CN2 China Telecom Next Generation Carrier Network, CN
18	45891	42861	0.47%	22	1948.23	SBT-AS-AP Solomon Telekom Co Ltd, SB
19	58224	42312	0.47%	804	52.63	TCI, IR
20	28605	41923	0.46%	45	931.62	Defferrari Informática Ltda., BR
21	14600	41392	0.46%	7	5913.14	MXL-PROD - MX Logic, Inc., US
22	23201	40326	0.45%	283	142.49	Telecel S.A., PY
23	32708	39167	0.43%	510	76.80	ROOTNETWORKS - Root Networks, LLC, US
24	36040	37487	0.41%	53	707.30	YOUTUBE - Google LLC, US
25	3832	34834	0.39%	20	1741.70	CINE-NET - Cinenet Communications, US
26	36974	34579	0.38%	106	326.22	AFNET-AS, CI
27	27064	34186	0.38%	867	39.43	DNIC-ASBLK-27032-27159 - DoD Network Information Center, US
28	28158	33125	0.37%	43	770.35	Ampernet Telecomunicações Ltda, BR

50 Most active Prefixes for the past 14 days

RANK	PREFIX	UPDs	%	Origin AS -- AS NAME
1	208.65.144.0/24	37872	0.41%	14600 -- MXL-PROD - MX Logic, Inc., US
2	104.237.191.0/24	37195	0.40%	36040 -- YOUTUBE - Google LLC, US
3	1.10.212.0/24	35291	0.38%	23969 -- TOT-NET TOT Public Company Limited, TH
4	216.238.254.0/23	32517	0.35%	13904 -- COSLINK - Cherryland Services Inc, US
5	103.200.16.0/24	32380	0.35%	134630 -- PALAPANET-AS-ID PT Palapa Global Nusantara, ID
6	103.200.19.0/24	32294	0.35%	134630 -- PALAPANET-AS-ID PT Palapa Global Nusantara, ID
7	27.124.80.0/24	27322	0.29%	38527 -- MLINK-AS-ID JAWA POS NATIONAL NETWORK MEDIALINK, PT, ID
8	24.139.172.0/24	26318	0.28%	14638 -- LCPRL - Liberty Cablevision of Puerto Rico, US
9	154.82.69.0/24	24551	0.26%	32708 -- ROOTNETWORKS - Root Networks, LLC, US
10	27.124.84.0/24	24332	0.26%	38527 -- MLINK-AS-ID JAWA POS NATIONAL NETWORK MEDIALINK, PT, ID
11	27.124.83.0/24	24303	0.26%	38527 -- MLINK-AS-ID JAWA POS NATIONAL NETWORK MEDIALINK, PT, ID
12	196.62.140.0/24	21008	0.23%	132165 -- CONNECT-AS-AP Connect Communications, PK
13	196.62.225.0/24	20997	0.23%	132165 -- CONNECT-AS-AP Connect Communications, PK
14	196.62.224.0/24	20993	0.23%	132165 -- CONNECT-AS-AP Connect Communications, PK
15	199.245.187.0/24	17423	0.19%	3832 -- CINE-NET - Cinenet Communications, US
16	198.148.151.0/24	17393	0.19%	3832 -- CINE-NET - Cinenet Communications, US
17	64.70.30.0/24	16034	0.17%	3561 -- CENTURLINK-LEGACY-SAVVIS - CenturyLink Communications, LLC, US
18	214.27.168.0/22	15477	0.17%	27064 -- DNIC-ASBLK-27032-27159 - DoD Network Information Center, US
19	214.4.251.0/24	15431	0.17%	27064 -- DNIC-ASBLK-27032-27159 - DoD Network Information Center, US
20	121.248.60.0/24	14635	0.16%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
21	121.248.192.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
22	121.249.16.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
23	121.249.48.0/22	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
24	121.248.184.0/21	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
25	121.248.160.0/21	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
26	121.249.32.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
27	121.248.208.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
28	121.248.224.0/19	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
29	121.249.0.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
30	121.248.176.0/21	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
31	121.248.168.0/21	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
32	121.248.96.0/20	14147	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
33	121.248.16.0/20	14146	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN
34	121.248.0.0/20	14146	0.15%	4538 -- ERX-CERNET-BKB China Education and Research Network Center, CN



IPv4 Observations

- Routing table continues to grow
 - Linear growth for last 8 years
 - Even though total address space announced has levelled off over the last 3 years
- /24 announcements continue to grow
 - Clearly many operators are deaggregating down to the smallest prefix size considered routable
 - Do operators still filter prefix sizes smaller than /24?
 - (A few /25s through /32s are visible)
- Overall global deaggregation ratio growth has slowed
 - Significant improvements in Latin America



IPv6 Observations

- Routing table growing more quickly in 2018
 - More deployment, or more deaggregation?
- /48 announcements continue to grow
 - Operators seem to believe that IPv6 /48 needs to be treated like IPv4 /24 ☹️
- Noticeable increases:
 - According to RIR allocation boundaries
 - Along nibble boundaries



Internet Routing Table Analysis Update

Questions?