

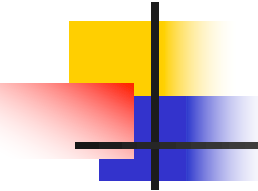
Internet Routing Table Analysis Update

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SANOG 35

20th January 2020

Karachi, Pakistan



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 19th January 2020

BGP routing table entries examined:	791429
Prefixes after maximum aggregation (per Origin AS):	301355
Deaggregation factor:	2.63
Unique aggregates announced (without unneeded subnets):	387591
Total ASes present in the Internet Routing Table:	66747
Prefixes per ASN:	11.86
Origin-only ASes present in the Internet Routing Table:	57362
Transit ASes present in the Internet Routing Table:	9385
Transit-only ASes present in the Internet Routing Table:	288
Average AS path length visible in the Internet Routing Table:	4.5
Max AS path length visible:	39
Max AS path prepend of ASN (53176)	31
Prefixes from unregistered ASNs in the Routing Table:	1318
Prefixes being announced from unallocated address space:	443
Number of addresses announced to Internet:	2853149056
Equivalent to 170 /8s, 15 /16s and 153 /24s	
Total number of prefixes smaller than registry allocations:	264777

APNIC Region

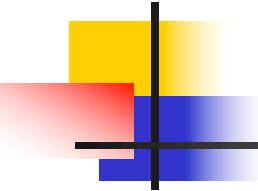
Prefixes being announced by APNIC Region ASes:	210368
Total APNIC prefixes after maximum aggregation:	61262
APNIC Deaggregation factor:	3.43
Prefixes being announced from the APNIC address blocks:	203895
Unique aggregates announced from the APNIC address blocks:	84940
APNIC Region origin ASes present in the Internet Routing Table:	10293
APNIC Prefixes per ASN:	19.81
APNIC Region origin ASes announcing only one prefix:	2851
APNIC Region transit ASes present in the Internet Routing Table:	1541
Average APNIC Region AS path length visible:	4.6
Max APNIC Region AS path length visible:	25
Number of APNIC addresses announced to Internet:	768063744
Equivalent to 45 /8s, 199 /16s and 185 /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, 131072-141625
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

Global per AS prefix count summary

ASN	No of nets	/20 equiv	Max Agg	Description
8151	6191	3297	610	Uninet S.A. de C.V., MX
12479	5851	1631	135	UNI2-AS, ES
7545	5248	645	604	TPG-INTERNET-AP TPG Telecom Limited, AU
4538	4621	4192	73	ERX-CERNET-BKB China Education and Rese
7155	4047	280	27	VIASAT-SP-BACKBONE, US
39891	4034	219	19	ALJAWWALSTC-AS, SA
11492	3894	258	653	CABLEONE, US
16509	3804	7735	1685	AMAZON-02, US
22773	3517	2971	152	ASN-CXA-ALL-CCI-22773-RDC, US
31334	3388	484	13	KABELDEUTSCHLAND-AS, DE
6327	3374	1324	94	SHAW, CA
10620	3362	533	465	Telmex Colombia S.A., CO
7552	3318	1331	24	VIETEL-AS-AP Viettel Group, VN
45899	3120	1785	107	VNPT-AS-VN VNPT Corp, VN
8551	3108	379	46	BEZEQ-INTERNATIONAL-AS Bezeqint Interne
16625	2956	1550	2122	AKAMAI-AS, US
20940	2819	469	1955	AKAMAI-ASN1, US
7713	2697	814	495	TELKOMNET-AS-AP PT Telekomunikasi Indon
11830	2680	369	63	Instituto Costarricense de Electricidad
9808	2600	9043	62	CMNET-GD Guangdong Mobile Communication

AfriNIC APNIC ARIN LACNIC RIPE NCC



Unassigned resources

- Use of unassigned address space is rampant
 - Currently 443 unassigned prefixes in IPv4 routing table
- Use of unassigned ASNs is also a big problem
 - Currently 385 unassigned ASNs in use
- Many are transited by well known / reputable operators
 - Why??

List of Unregistered Origin ASNs (Global)

The complete list in use:

1631, 1636, 4890, 5116, 6292, 6485, 7124, 7363, 7619, 7837, 10425, 10926, 10931, 10981, 11011, 11044,
11247, 11316, 11480, 11490, 11531, 11636, 11945, 11969, 12017, 12071, 12077, 12122, 12176, 12195, 12226,
12232, 12240, 13317, 13334, 13339, 13405, 13622, 13847, 14076, 14109, 14350, 14360, 14428, 14461, 14552,
14651, 14725, 14880, 14889, 15037, 15040, 15115, 15132, 15182, 15200, 15206, 15220, 15240, 15289, 15329,
15333, 16512, 16554, 16581, 16636, 16753, 16769, 16797, 16808, 16903, 17076, 17344, 18457, 18493, 18548,
18691, 18781, 18796, 18805, 18996, 19081, 19111, 19142, 19330, 19521, 19533, 19606, 19658, 19708, 19901,
19926, 20067, 20089, 20137, 20138, 20184, 20190, 20421, 20443, 21629, 21665, 21666, 21682, 21695, 21714,
21861, 21986, 22063, 22160, 22272, 22280, 22284, 22295, 22338, 22482, 22484, 22538, 22539, 22613, 22694,
22733, 22736, 22740, 22743, 22774, 22830, 22963, 23061, 23071, 23194, 23448, 23474, 23475, 23537, 25568,
25600, 25618, 25800, 25831, 25849, 25879, 25890, 25978, 25980, 26006, 26009, 26015, 26016, 26018, 26042,
26051, 26140, 26195, 26232, 26286, 26295, 26377, 26522, 26561, 26643, 26757, 26787, 26799, 26861, 26922,
26986, 27010, 27174, 27205, 27289, 27384, 27386, 27426, 27470, 28303, 29703, 29769, 29829, 29855, 30004,
30037, 30104, 30155, 30265, 30307, 30433, 30463, 30550, 30631, 30699, 31781, 31813, 32121, 32128, 32151,
32202, 32203, 32282, 32346, 32358, 32422, 32436, 32581, 32591, 32596, 32663, 32772, 32985, 33020, 33023,
33046, 33051, 33118, 33136, 33158, 33245, 33381, 33394, 33396, 33417, 33448, 33484, 33617, 33625, 33628,
33679, 33691, 35846, 35948, 35996, 36002, 36262, 36357, 36461, 36465, 36672, 36706, 36777, 36843, 36886,
36900, 37007, 37023, 37149, 37265, 37382, 37434, 37448, 37587, 37981, 39012, 39408, 39991, 40172, 40186,
40255, 40279, 40329, 40537, 40544, 40600, 40617, 40745, 40751, 40891, 40909, 40920, 46080, 46086, 46087,
46123, 46161, 46228, 46233, 46318, 46414, 46472, 46505, 46644, 46645, 46673, 46783, 46815, 46967, 46978,
47044, 47055, 47693, 49271, 50598, 53128, 53141, 53358, 53552, 53572, 53614, 53622, 53627, 53651, 53657,
53715, 53751, 53761, 53771, 53929, 53947, 54041, 54309, 54415, 54590, 54681, 54730, 54753, 54776, 54787,
54941, 55040, 55285, 55827, 56096, 59906, 62485, 62702, 62746, 62828, 63001, 63013, 63200, 63248, 63387,
63477, 64011, 64042, 64140, 64339, 64355, 64506, 64510, 65537, 65540, 65544, 65550, 65552, 65553, 65595,
133025, 133926, 136511, 137978, 200840, 207089, 230105, 260984, 262271, 262678, 263862, 264085, 265789,
265926, 266842, 267874, 327074, 328058, 328117, 328166, 393266, 393320, 393377, 393385, 393491, 393588,
393866, 394039, 394218, 394402, 394519, 394721, 394879, 394936, 395222, 395424, 395438, 395596, 396444

List of Unregistered Origin ASNs (Global)

Bad AS	Designation	Net Originated	Transit AS	Transit AS Name
17076	UNALLOCATED	8.12.244.0/24	3356	LEVEL3, US
62828	UNALLOCATED	8.21.130.0/24	3356	LEVEL3, US
393266	UNALLOCATED	8.23.52.0/24	174	COGENT-174, US
62485	UNALLOCATED	8.23.229.0/24	3356	LEVEL3, US
32985	UNALLOCATED	8.28.31.0/24	3356	LEVEL3, US
394936	UNALLOCATED	8.33.224.0/24	174	COGENT-174, US
23071	UNALLOCATED	8.33.235.0/24	3356	LEVEL3, US
27205	UNALLOCATED	8.38.16.0/21	6461	ZAYO-6461, US
27205	UNALLOCATED	8.38.16.0/22	32787	PROLEXIC-TECHNOLOGIES-DDOS-M
27205	UNALLOCATED	8.38.20.0/22	32787	PROLEXIC-TECHNOLOGIES-DDOS-M
14109	UNALLOCATED	8.38.252.0/24	3356	LEVEL3, US
23061	UNALLOCATED	8.39.119.0/24	3356	LEVEL3, US
395438	UNALLOCATED	8.42.206.0/24	3356	LEVEL3, US
40544	UNALLOCATED	12.0.33.0/24	6461	ZAYO-6461, US
33628	UNALLOCATED	12.0.239.0/24	1239	SPRINTLINK, US
46505	UNALLOCATED	12.7.131.0/24	7018	ATT-INTERNET4, US
15132	UNALLOCATED	12.9.150.0/24	1239	SPRINTLINK, US
22280	UNALLOCATED	12.10.217.0/24	701	UUNET, US
19111	UNALLOCATED	12.13.211.0/24	7018	ATT-INTERNET4, US

...etc...

List of Unassigned addresses (Global)

Far too many to list individually. Here are the first few:

Unassigned Network	ASN Information	AS Name
23.136.224.0/24	Origin: 15206	UNASSIGNED
	Transit: 174	COGENT-174, US
23.137.192.0/24	Origin: 31798	CANAD-86-31798, CA
	Transit: 6939	HURRICANE, US
27.100.7.0/24	Origin: 56096	UNASSIGNED
	Transit: 45455	TH-2S1N-AP Two S One N Co Ltd, Internet
27.126.156.0/22	Origin: 55827	UNASSIGNED
	Transit: 9930	TTNET-MY TIME dotCom Berhad, MY
27.126.156.0/23	Origin: 55827	UNASSIGNED
	Transit: 9930	TTNET-MY TIME dotCom Berhad, MY
27.126.158.0/23	Origin: 55827	UNASSIGNED
	Transit: 9930	TTNET-MY TIME dotCom Berhad, MY
41.67.192.0/18	Origin: 15964	CAMNET-AS, CM
	Transit: 12956	TELEFONICA TELXIUS, ES
41.67.192.0/24	Origin: 15964	CAMNET-AS, CM
	Transit: 12956	TELEFONICA TELXIUS, ES
<snip>		
43.229.16.0/22	Origin: 136800	XIAOZHUYUN1-AS-AP ICIDC NETWORK, US
	Transit: 64050	BCPL-SG BGPNET Global ASN, SG
45.221.25.0/24	Origin: 328117	UNASSIGNED
	Transit: 37098	globe-as, MW
45.252.236.0/22	Origin: 38803	WPL-AS-AP Wirefreebroadband Pty Ltd, AU
	Transit: 1221	ASN-TELSTRA Telstra Corporation Ltd, AU
64.30.152.0/24	Origin: 15830	EQUINIX-CONNECT-EMEA, GB
	Transit: 3257	GTT-BACKBONE GTT, DE

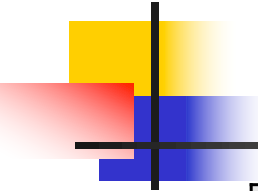
Number of prefixes announced by prefix length

/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:12
/9:10	/10:36	/11:99	/12:292	/13:568	/14:1129	/15:1917	/16:13358
/17:7881	/18:13838	/19:25541	/20:39660	/21:46167	/22:91397	/23:74725	/24:414525
/25:922	/26:827	/27:877	/28:20	/29:6	/30:1	/31:0	/32:190

19th January 2019 ↑

19th January 2020 ↓

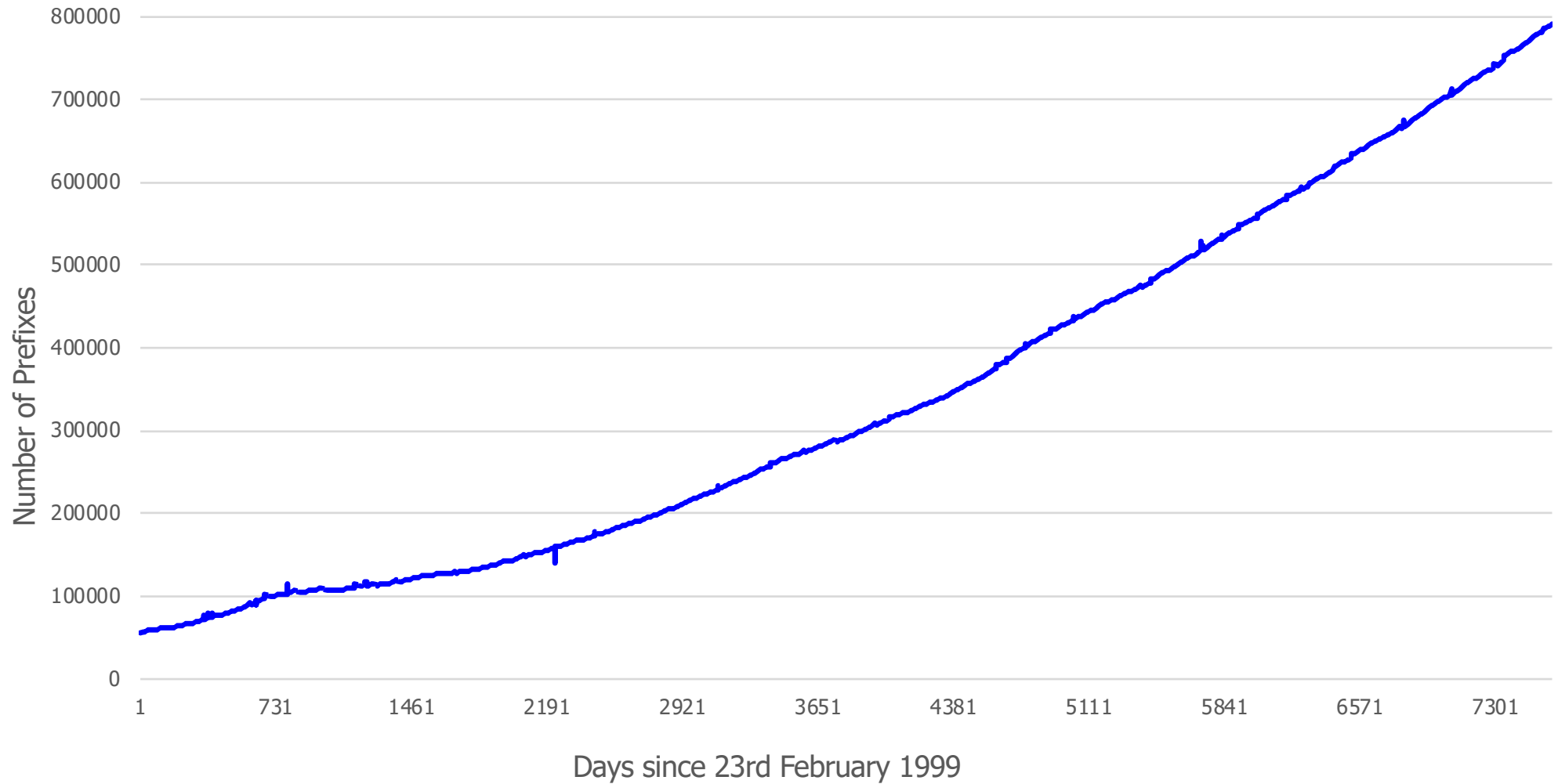
/1:0	/2:0	/3:0	/4:0	/5:0	/6:0	/7:0	/8:10
/9:11	/10:38	/11:98	/12:287	/13:580	/14:1159	/15:1921	/16:13390
/17:8129	/18:13871	/19:25805	/20:40471	/21:47581	/22:98449	/23:80758	/24:457536
/25:1335	/26:0	/27:0	/28:0	/29:0	/30:0	/31:0	/32:0



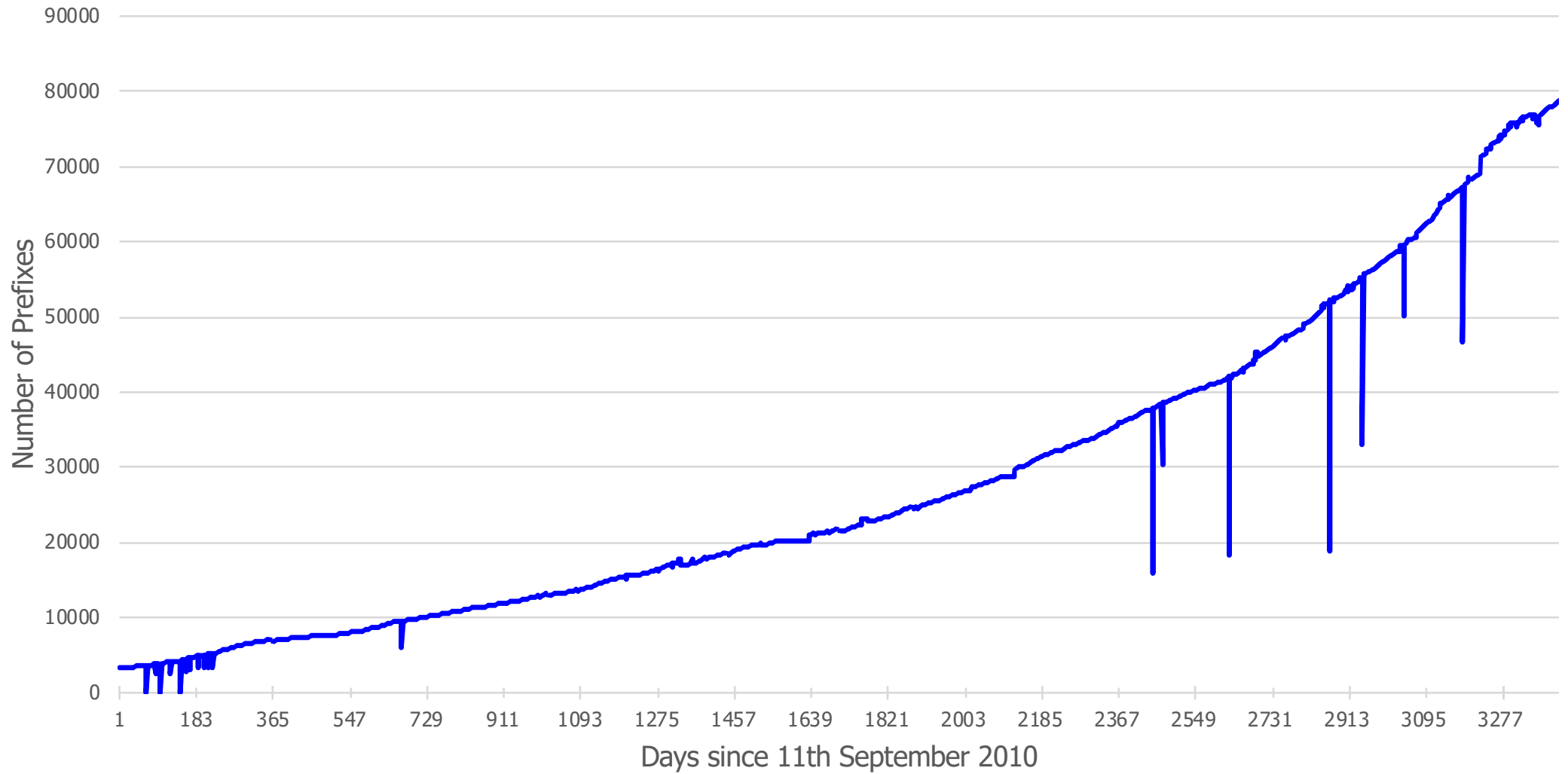
What about IPv6 ?

Table Size	78875
Number of /32s	13478
Number of /48s	38197
Number of prefixes >/48	0 ← ISP is Filtering 😊
Number of prefixes >/32 and </48	22067
Number of prefixes >/16 and </32	3645

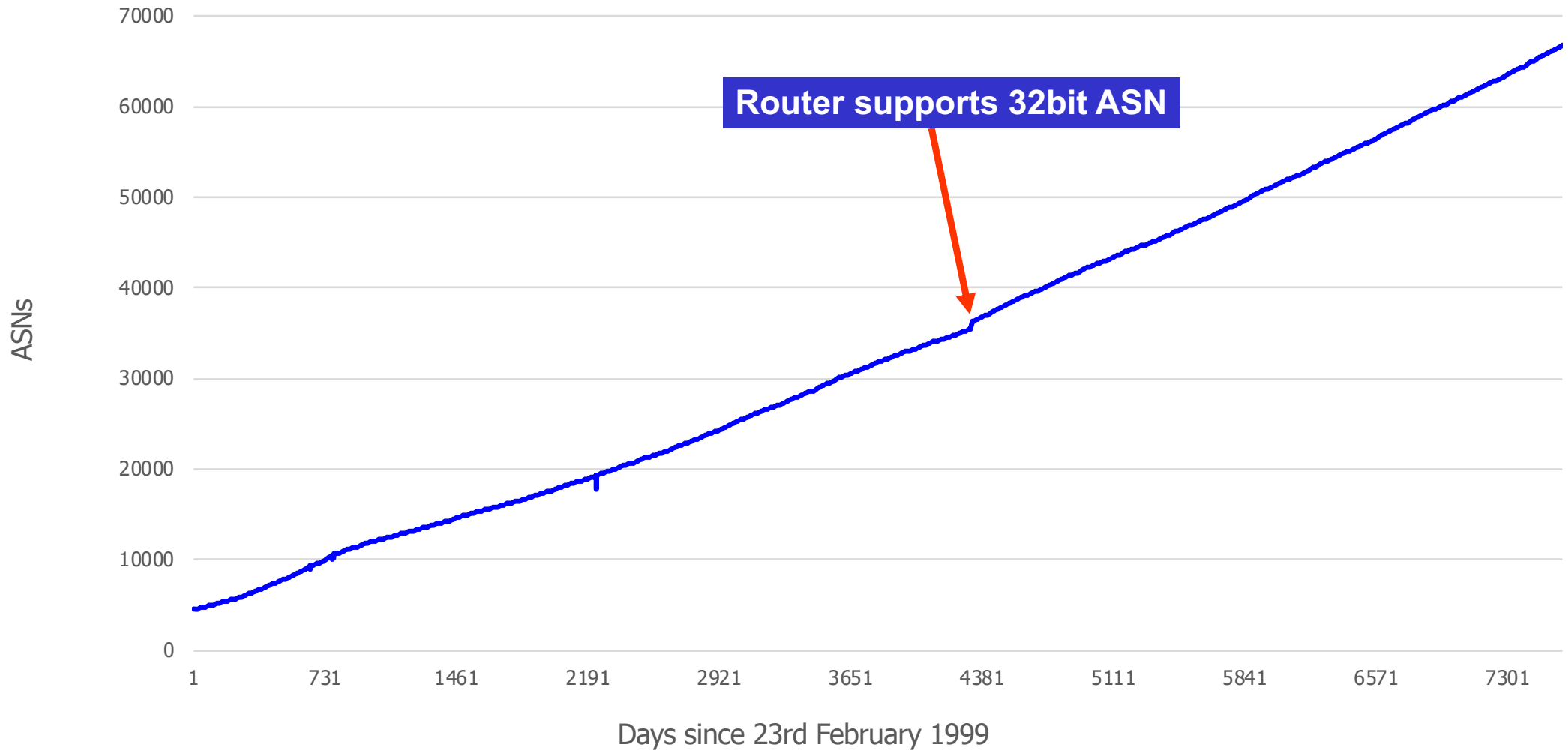
Global IPv4 Routing Table



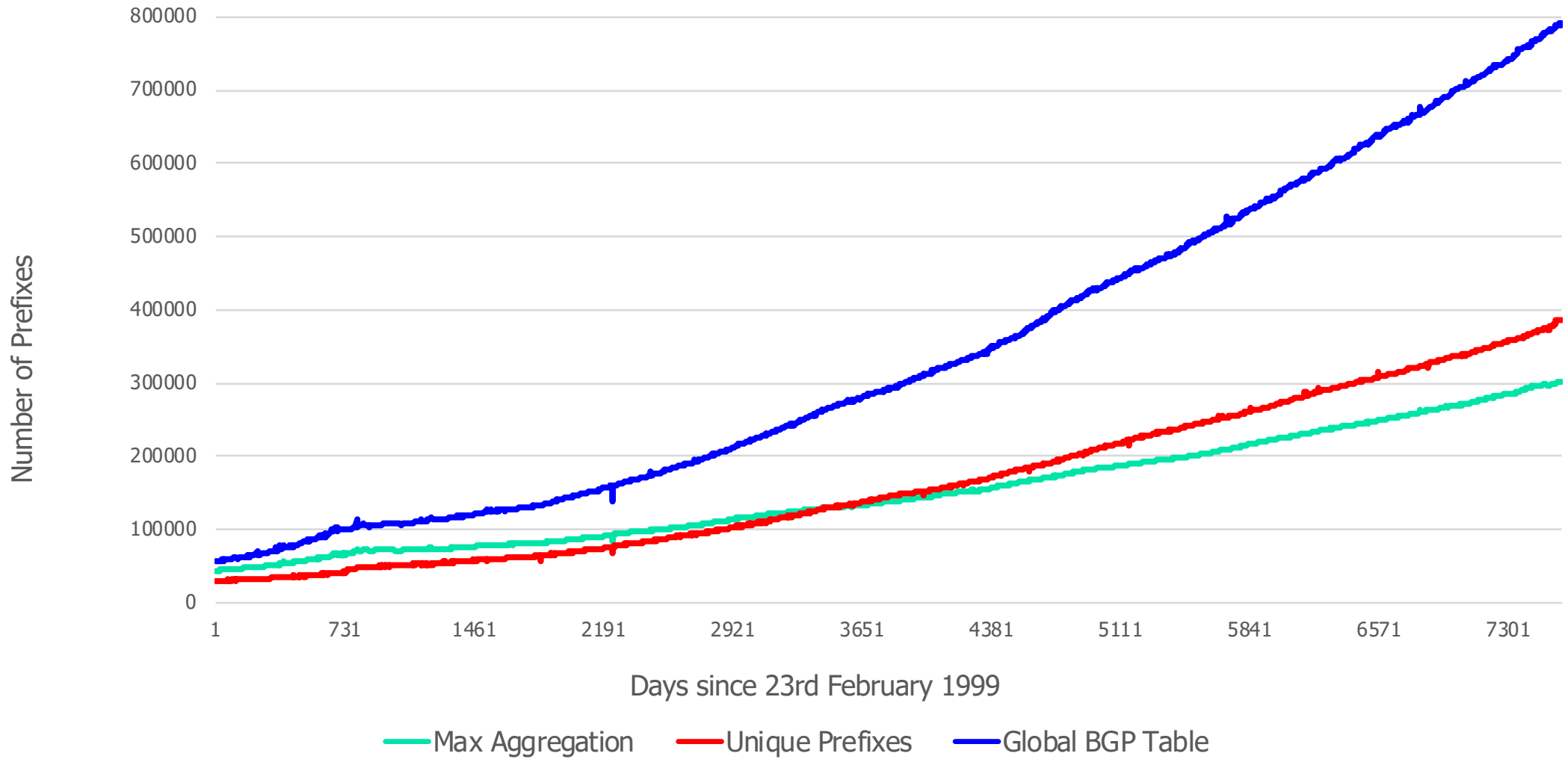
Global IPv6 Routing Table



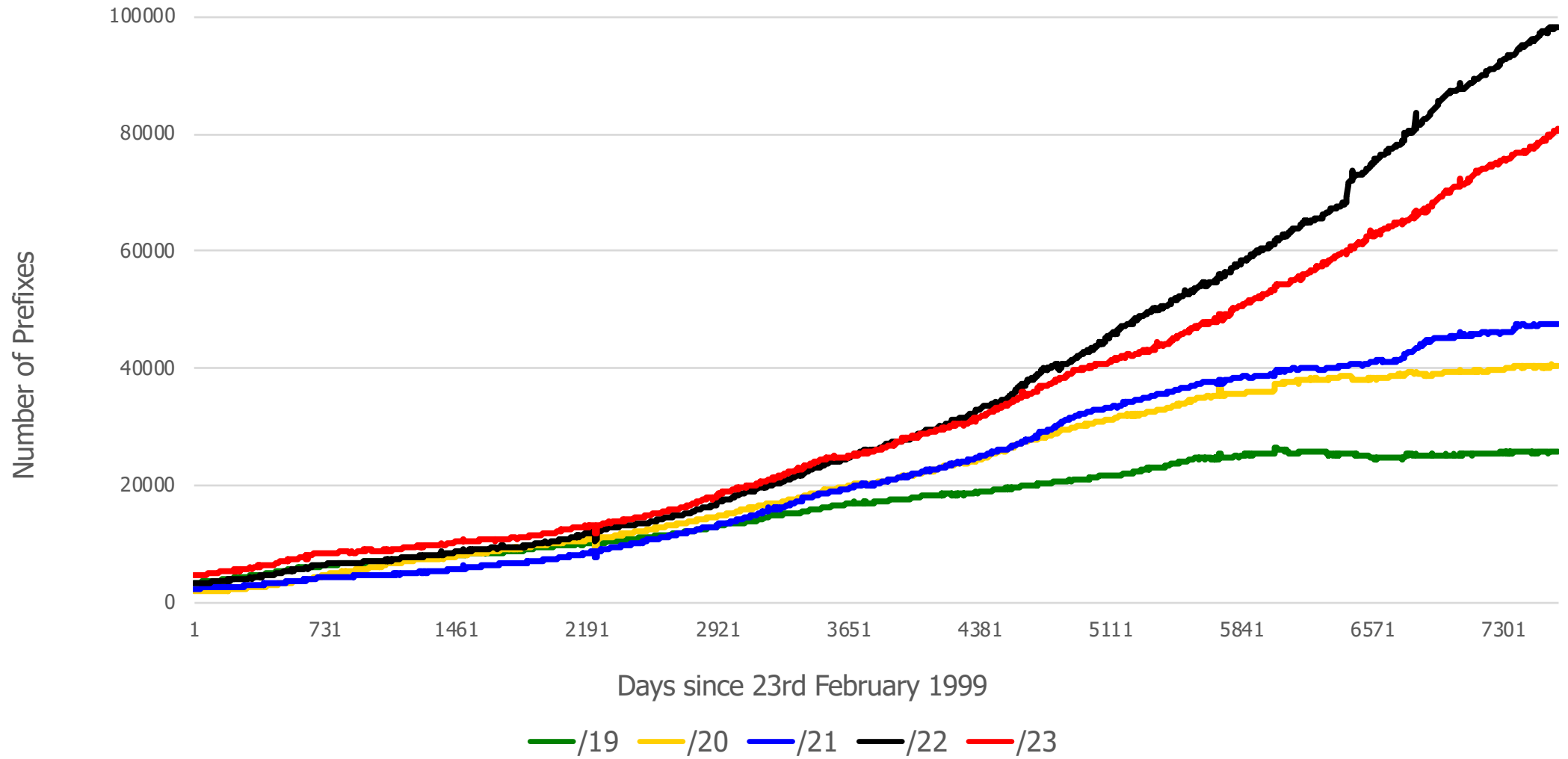
AS Growth



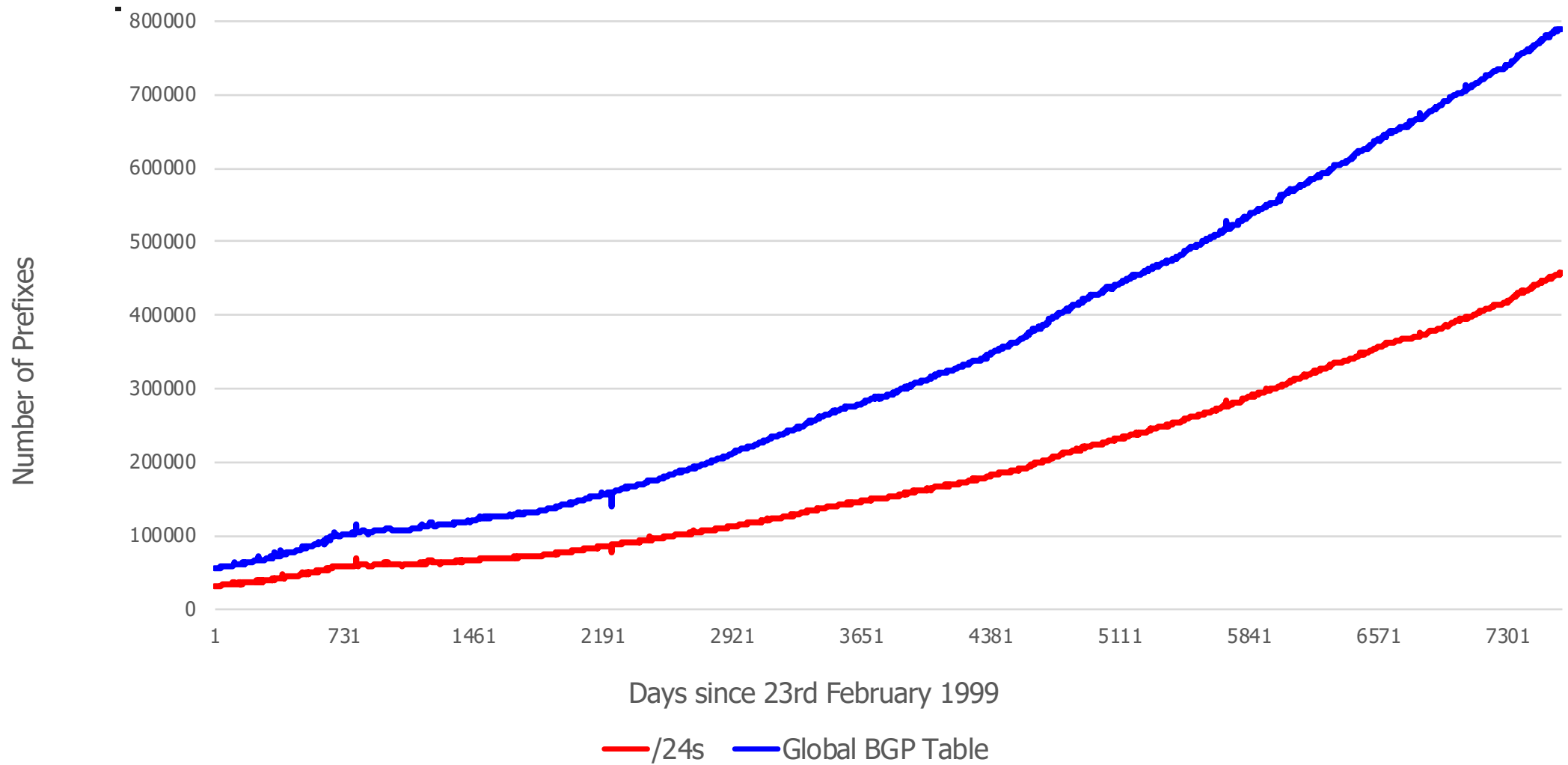
Max Aggregation vs Unique Prefixes



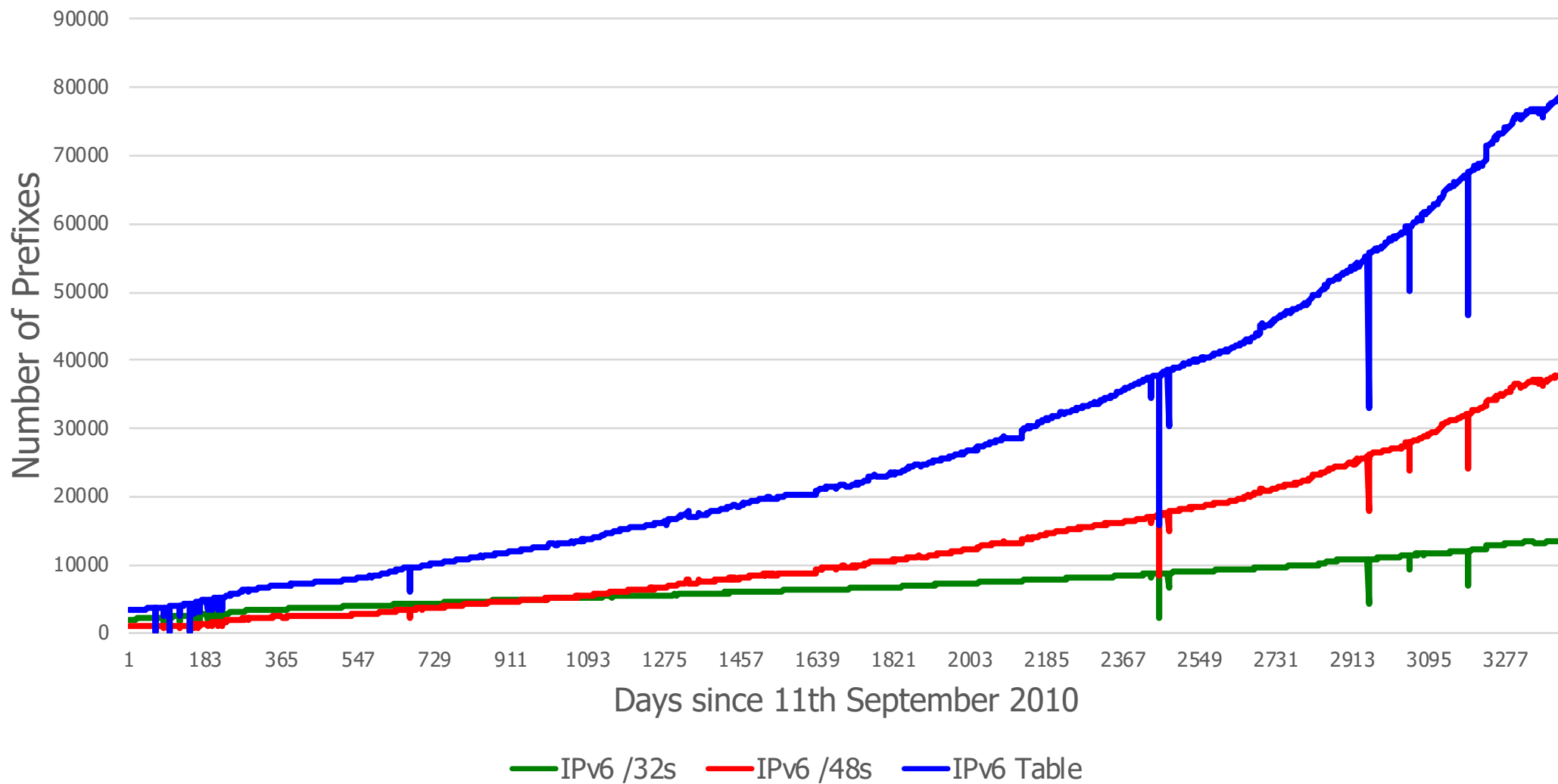
Prefix sizes announced



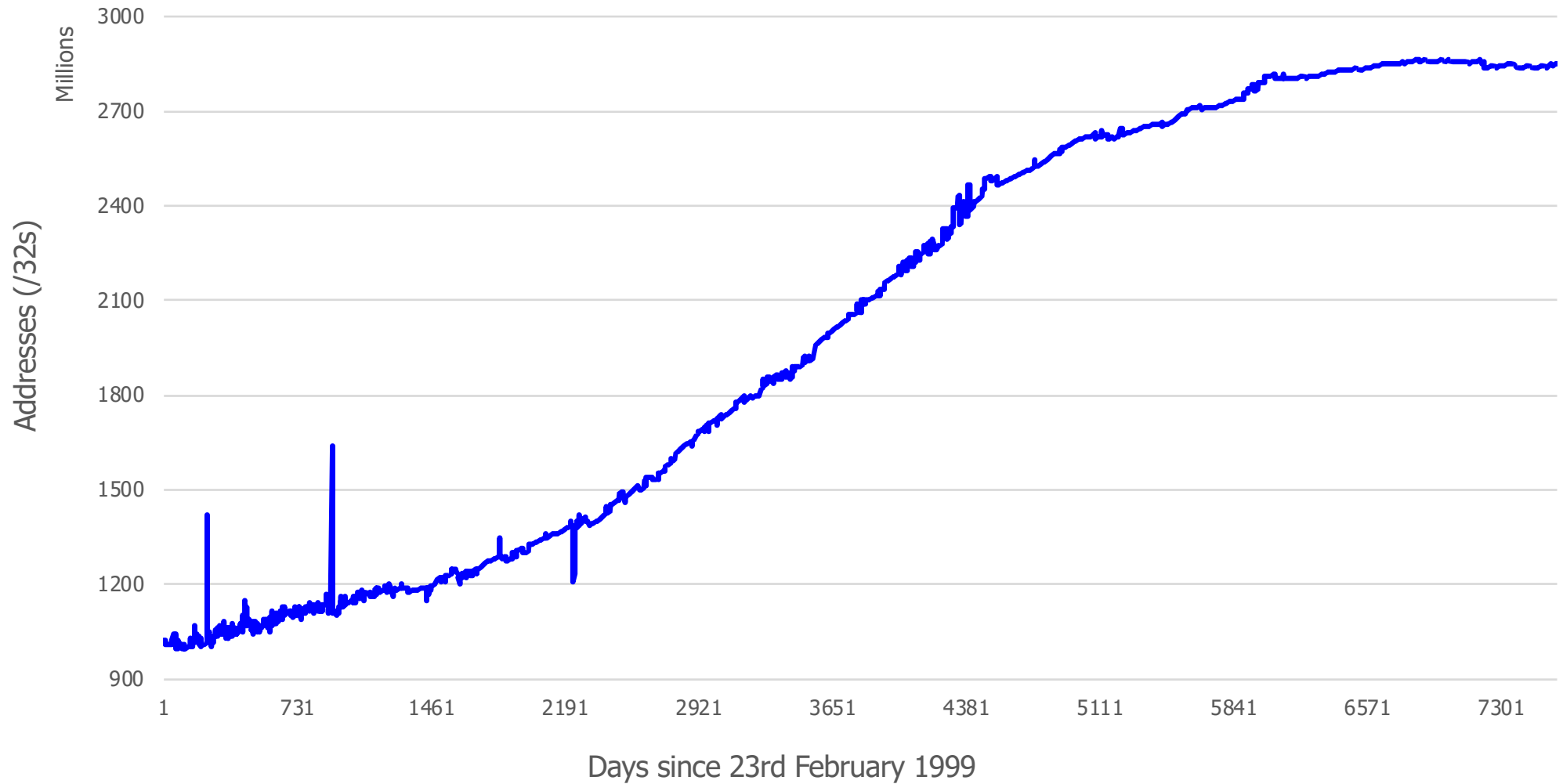
/24s announced



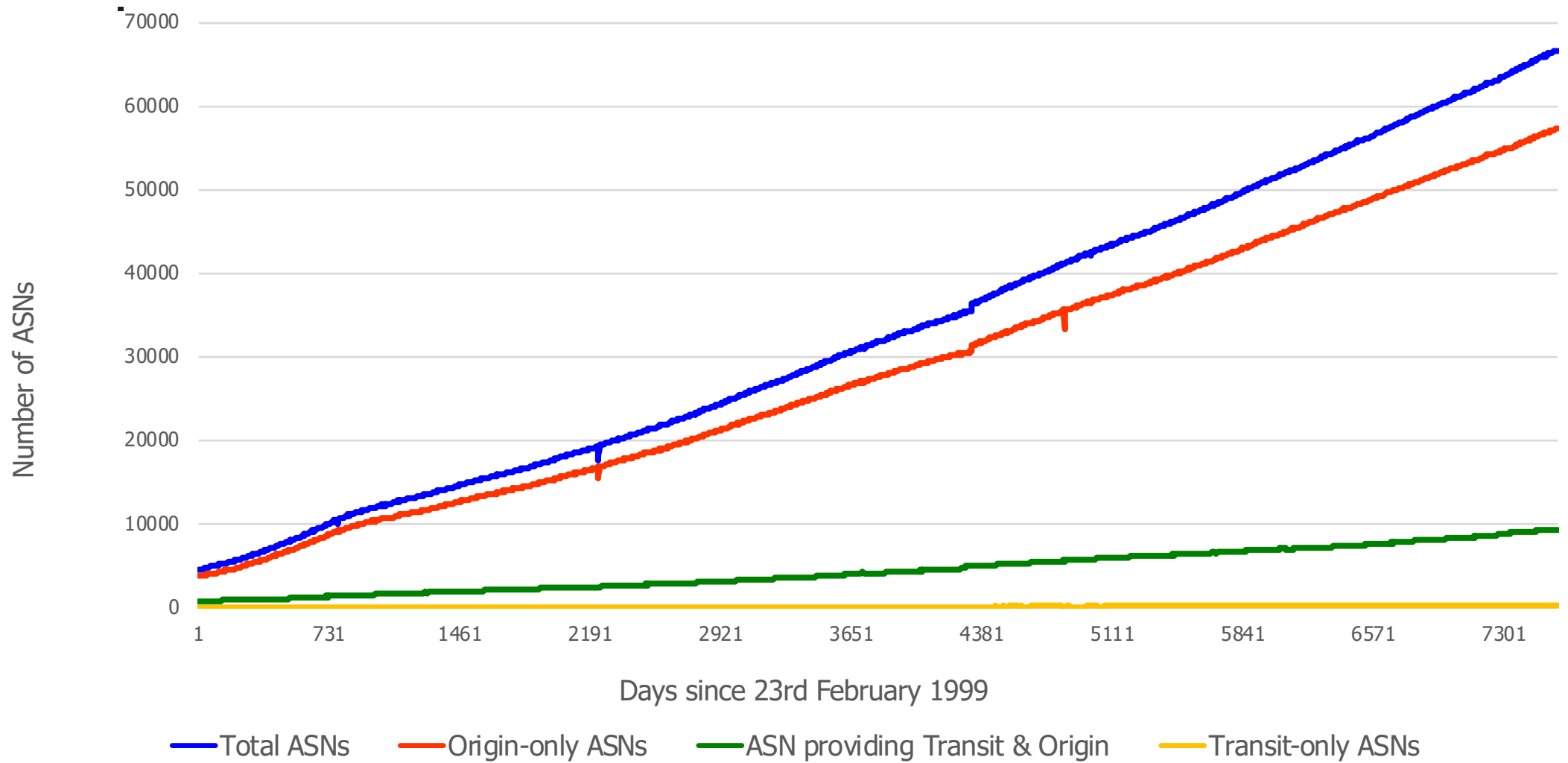
IPv6 /32s vs /48s



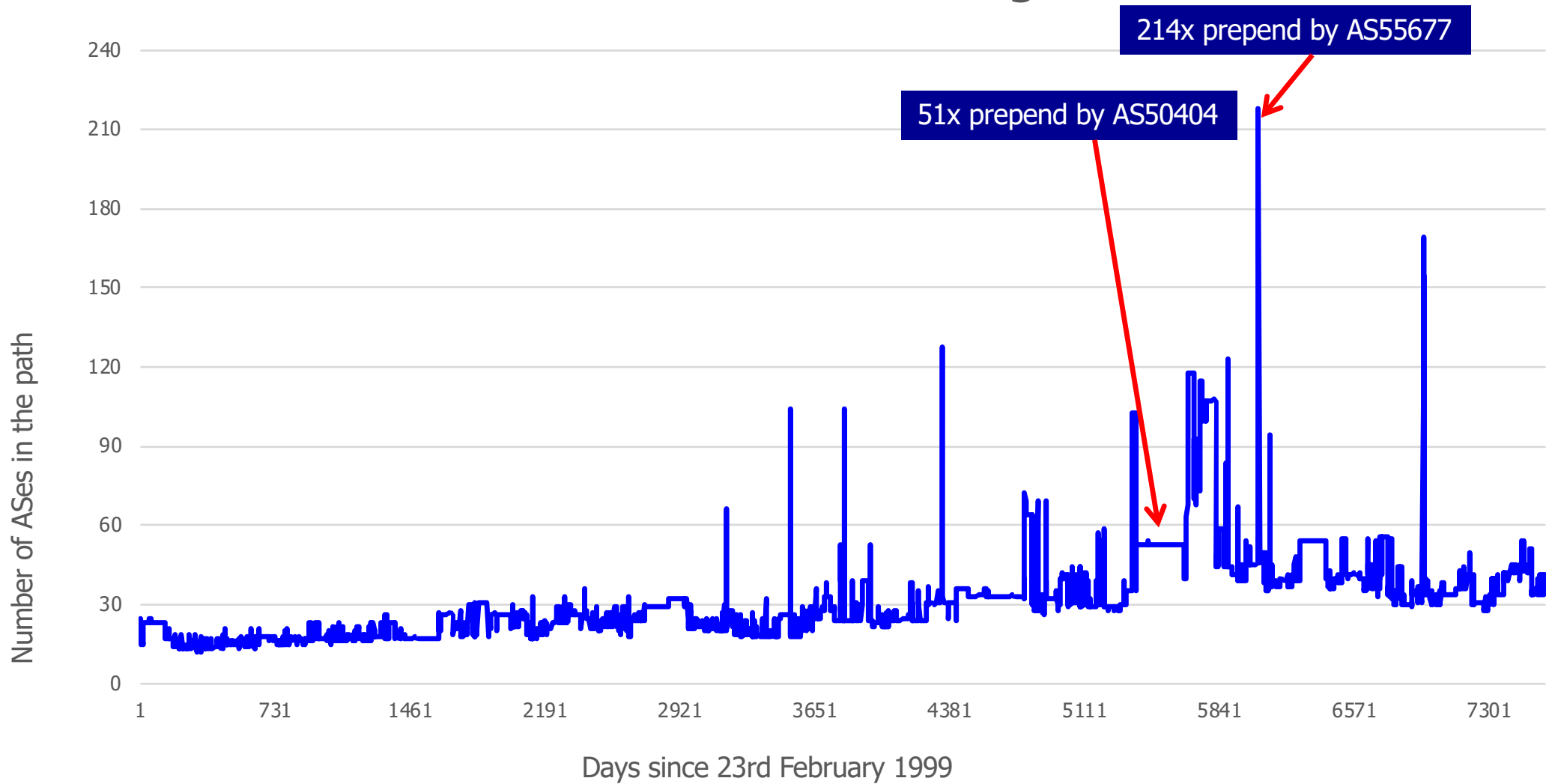
IPv4 Address Space announced

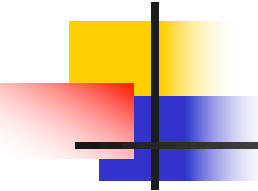


AS Announcements



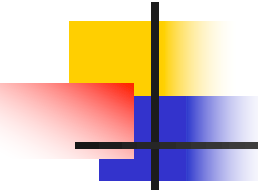
Maximum AS Path Length





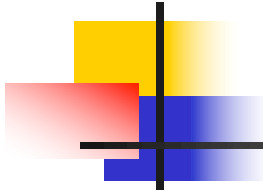
Looking at Deaggregation

- 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

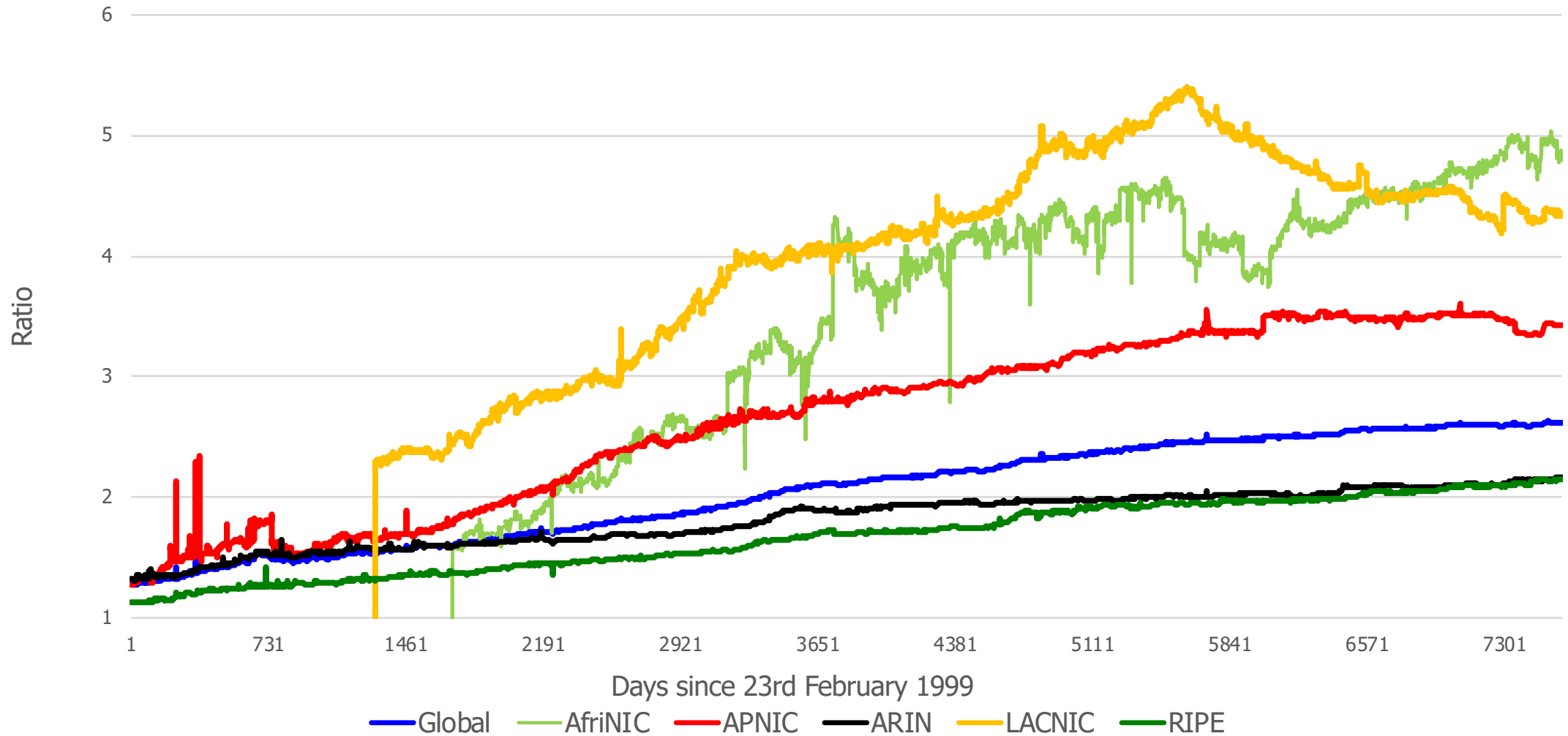
- Routing Report
 - One summary takes BGP table and aggregates prefixes by origin AS
 - Called “Max Aggregation” in report
 - Global and per RIR basis
 - <http://thyme.apnic.net/current/>
- Calculates **Deaggregation** Factor:
 - Measure of Routing Table size/Aggregated Size
 - Global value has been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



January 2020

- **Total Prefixes**
- Global BGP Table
 - 791k prefixes
- North America
 - 232k prefixes
- Europe & Middle East
 - 224k prefixes
- Asia & Pacific
 - 210k prefixes
- Latin America & Caribbean
 - 103k prefixes
- Africa
 - 21k prefixes
- **Deaggregation Factor**
- Global Average
 - 2.63
- North America
 - 2.16
- Europe & Middle East
 - 2.15
- Asia & Pacific
 - 3.43
- Latin America & Caribbean
 - 4.34
- Africa
 - 4.82

Deaggregation: RIR Regions vs Global



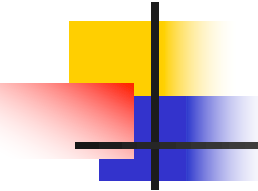
Asia Pacific Aggregation Savings Summary

ASN	No of Nets	Savings	Description
7545	5248	4644	TPG-INTERNET-AP TPG Telecom Limited, AU
4538	4621	4548	ERX-CERNET-BKB China Education and Research Net
7552	3318	3294	VIETEL-AS-AP Viettel Group, VN
45899	3120	3013	VNPT-AS-VN VNPT Corp, VN
9808	2600	2538	CMNET-GD Guangdong Mobile Communication Co.Ltd.
7713	2697	2202	TELKOMNET-AS-AP PT Telekomunikasi Indonesia, ID
9394	2096	2072	CTTNET China TieTong Telecommunications Corpora
9498	2218	2006	BBIL-AP BHARTI Airtel Ltd., IN
4755	2137	1947	TATACOMM-AS TATA Communications formerly VSNL i
9829	2160	1911	BSNL-NIB National Internet Backbone, IN
23969	1863	1847	TOT-NET TOT Public Company Limited, TH
45090	1788	1736	CNNIC-TENCENT-NET-AP Shenzhen Tencent Computer
4766	2264	1698	KIXS-AS-KR Korea Telecom, KR
134705	1851	1693	ITACE-AS-AP Itace International Limited, HK
56041	1267	1205	CMNET-ZHEJIANG-AP China Mobile communications c
9583	1690	1128	SIFY-AS-IN Sify Limited, IN
4808	1487	1105	CHINA169-BJ China Unicom Beijing Province Netwo
45609	1424	1080	BHARTI-MOBILITY-AS-AP Bharti Airtel Ltd. AS for
18403	1087	1048	FPT-AS-AP The Corporation for Financing & Promo
132165	1115	1037	CONNECT-AS-AP Connect Communications, PK

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

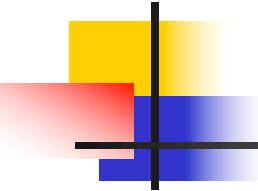
Pakistan Aggregation Savings Summary

ASN	No of Nets	Savings	Description
132165	1115	1037	CONNECT-AS-AP Connect Communications, PK
9541	503	404	CYBERNET-AP Cyber Internet Services (Pvt) Ltd.,
45595	401	389	PKTELECOM-AS-PK Pakistan Telecom Company Limite
38264	312	307	WATEEN-IMS-PK-AS-AP National WiMAX/IMS environm
23674	287	265	NAYATEL-PK Nayatel (Pvt) Ltd, PK
55714	239	177	APNIC-FIBERLINK-PK Fiberlink Pvt.Ltd, PK
45814	188	171	FARIYA-PK Fariya Networks Pvt. Ltd., PK
23966	172	160	LDN-AS-PK LINKdotNET Telecom Limited, PK
9260	136	120	MULTINET-AS-AP Multinet Pakistan Pvt. Ltd., PK
38710	123	102	WORLDCALL-AS-LHR Worldcall Broadband Limited, P
17563	137	99	NEXLINX-AS-AP Autonomous System Number for Nexl
17557	167	95	PKTELECOM-AS-PK Pakistan Telecommunication Comp
58895	143	89	EBONE1-PK Ebone Network (PVT.) Limited, PK
38616	102	79	WORLDCALL-AS-KHI Worldcall Telecom Limited, PK
136525	79	66	WANCOMPVTLTD-AS-AP Wancom (Pvt) Ltd., PK
136384	80	65	OPTIX-AS-AP Optix Pakistan (Pvt.) Limited, PK
17911	68	60	BRAINPK-AS-AP Brain Telecommunication Ltd., PK
7590	64	52	COMSATS Commission on Science and Technology fo
38193	88	52	TWA-AS-AP Transworld Associates (Pvt.) Ltd., PK
23888	63	51	NTC-AS-AP National Telecommunication Corporatio



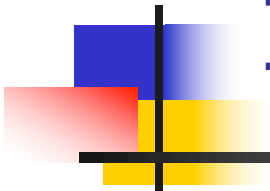
IPv4 Observations

- 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 growth slowed towards end of 2019
 - How to interpret this?
- /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?