BGP in 2011

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Conventional (Historical) BGP Wisdom

IAB Workshop on Inter-Domain routing in October 2006 – RFC 4984:

> **"routing scalability is the most important problem facing the Internet today and must be solved"**

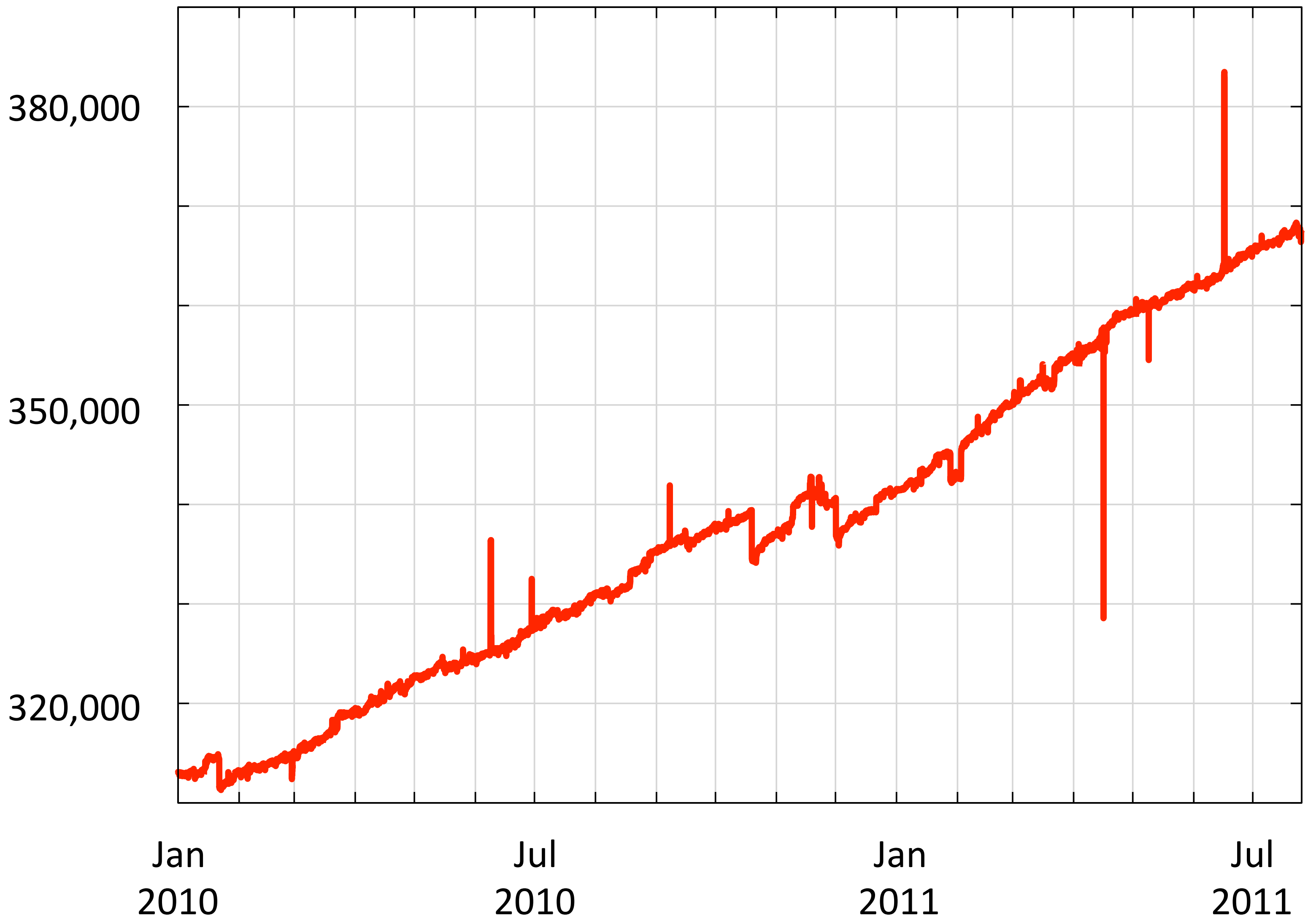
Conventional Wisdom

Conventional wisdom (CW) is a term used to describe ideas or explanations that are generally accepted as true by the public or by experts in a field. Such ideas or explanations, though widely held, are unexamined.*

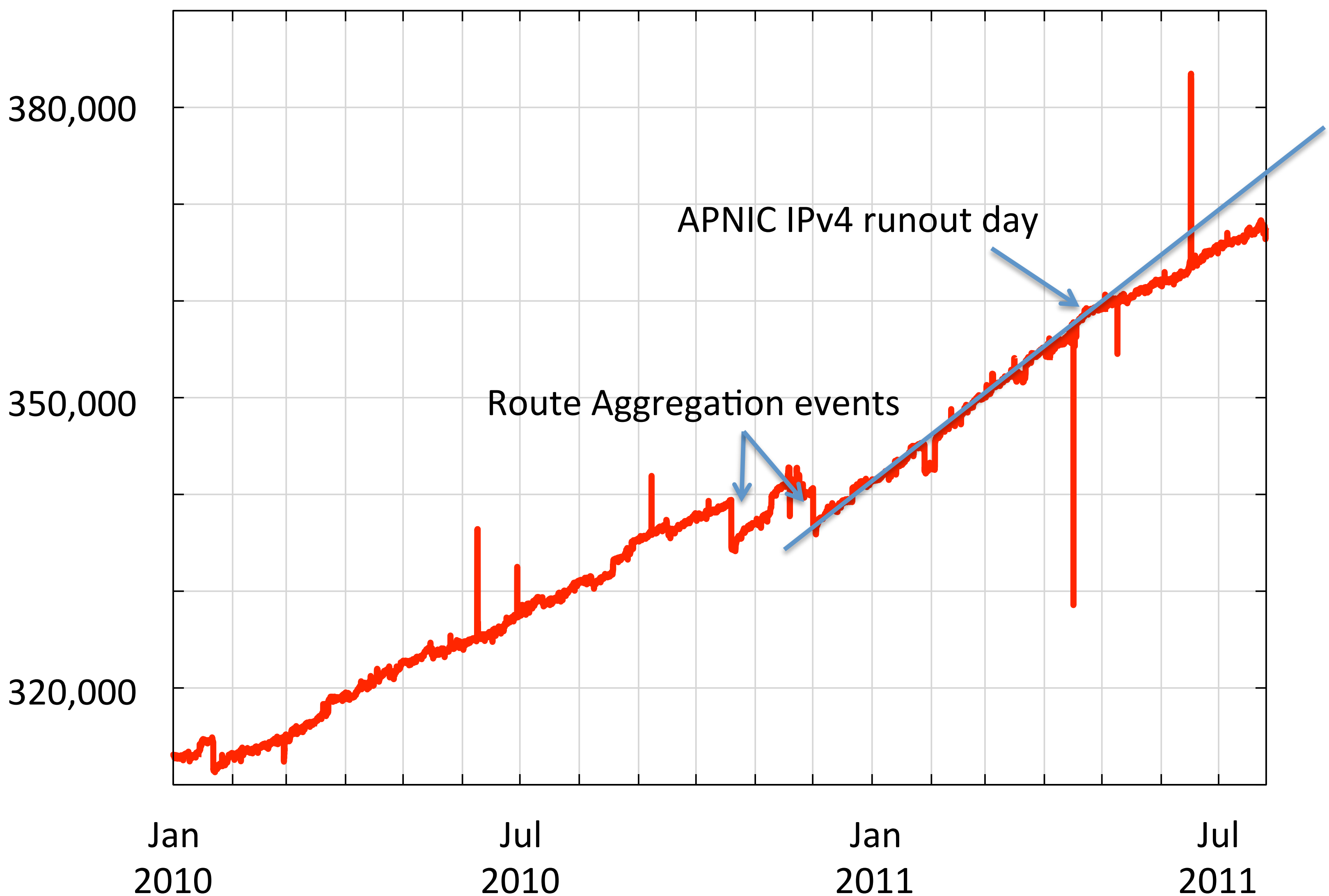
So lets examine this conventional wisdom relating to the scaling properties of BGP by looking at BGP in 2011...

* Ironically, I'll cite that renown source of conventional wisdom, Wikipedia (http://en.wikipedia.org/wiki/Conventional_wisdom)

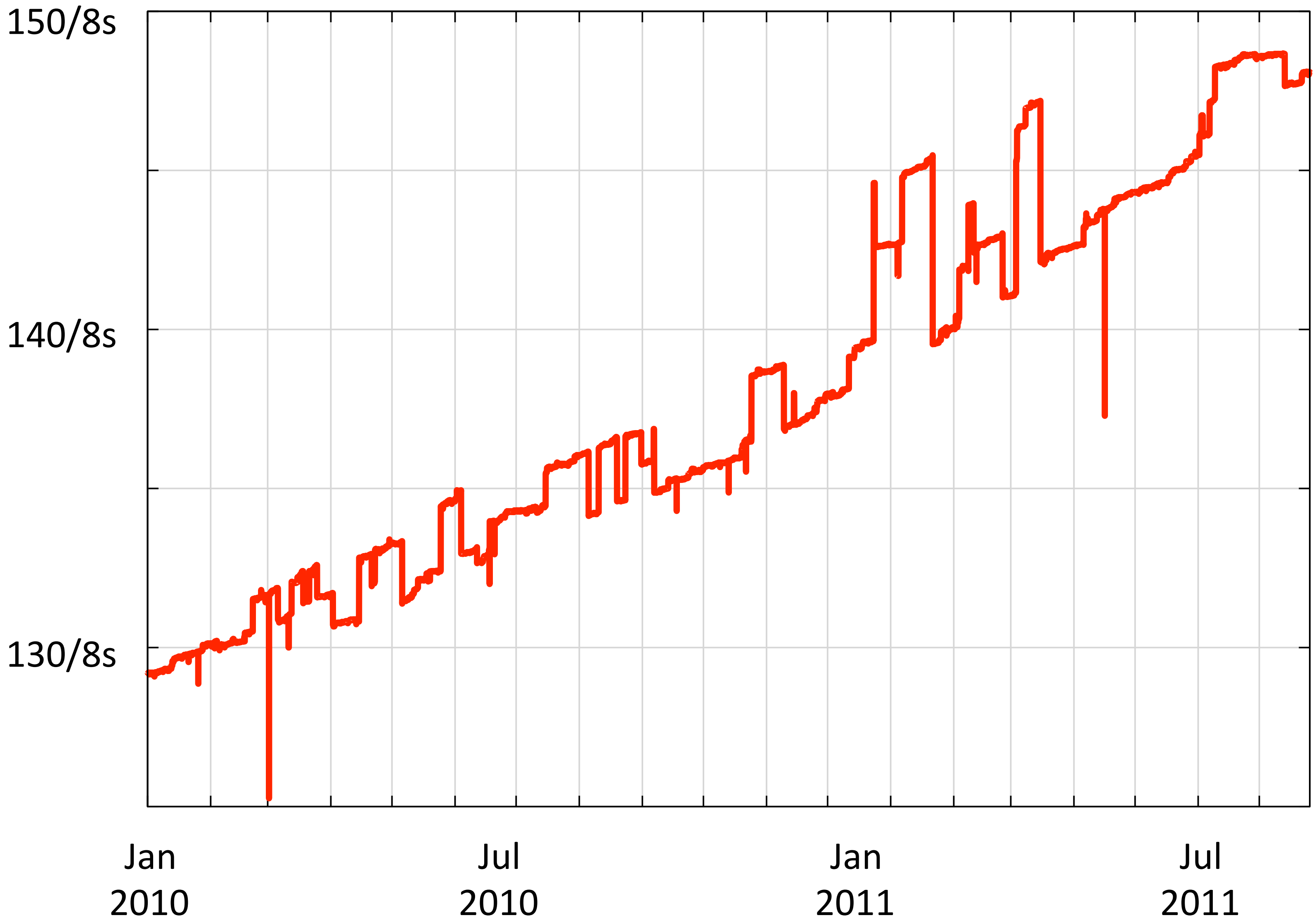
IPv4 BGP Prefix Count 2010 - 2011



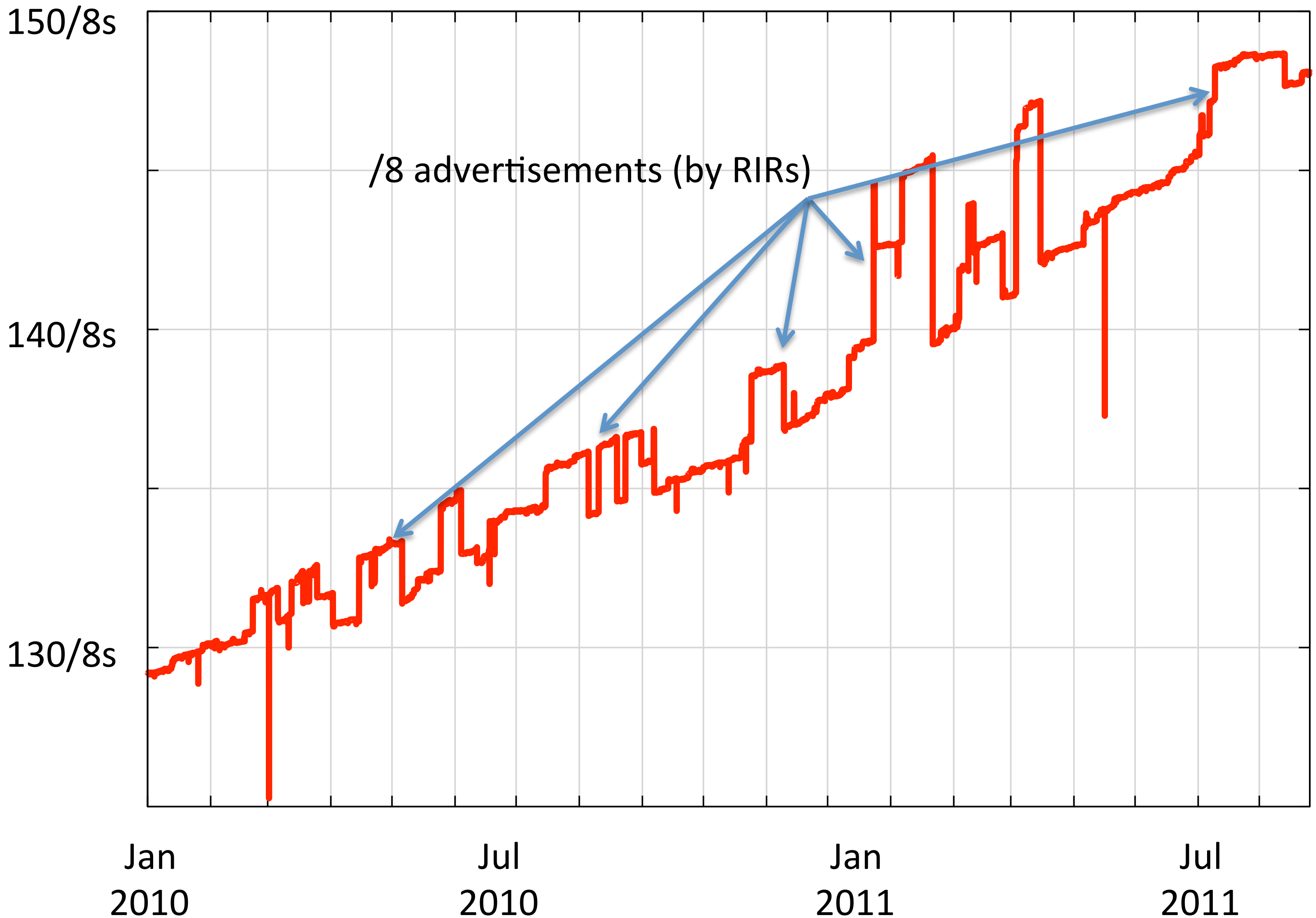
IPv4 BGP Prefix Count



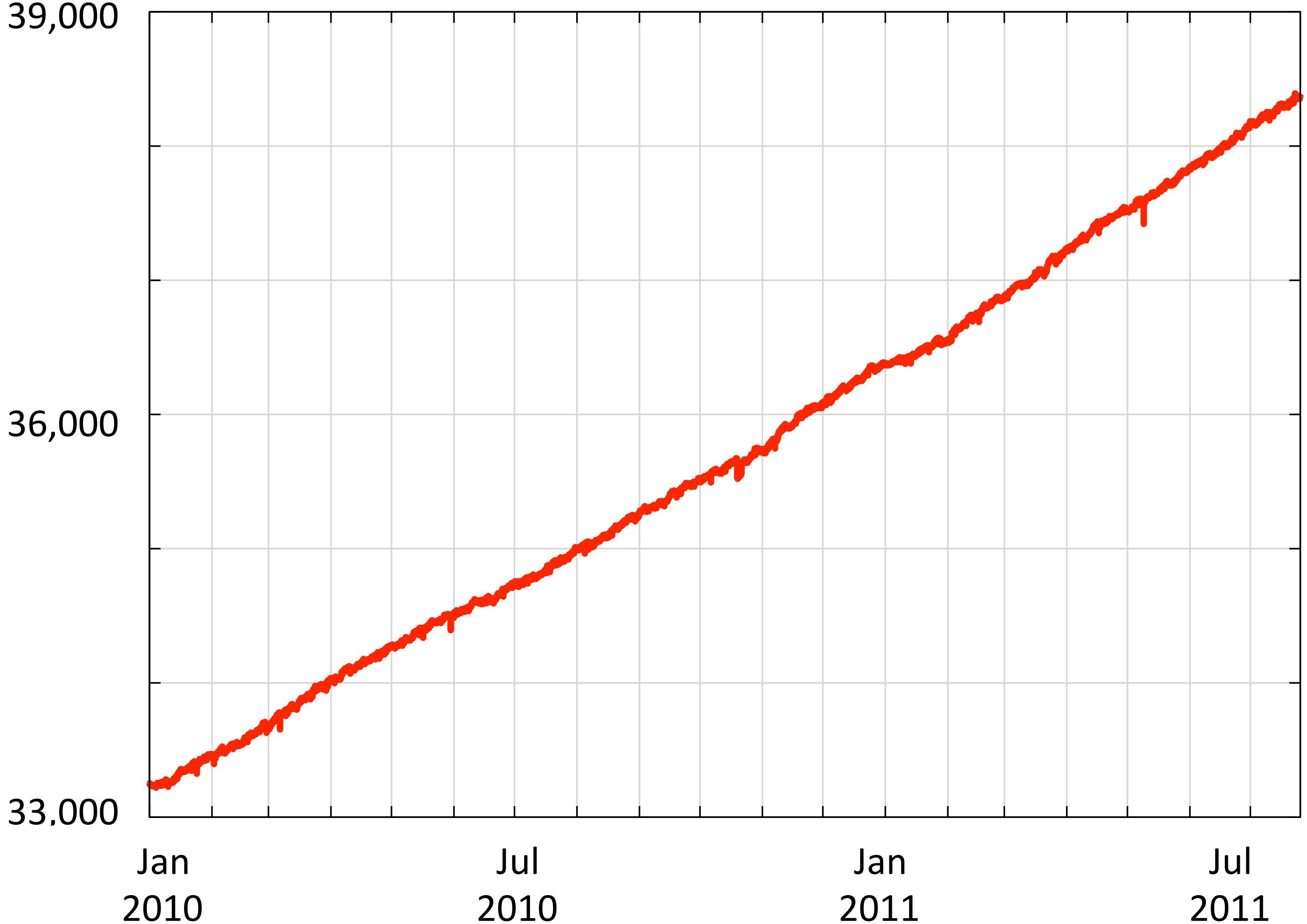
IPv4 Routed Address Span



IPv4 Routed Address Span



IPv4 Routed AS Count



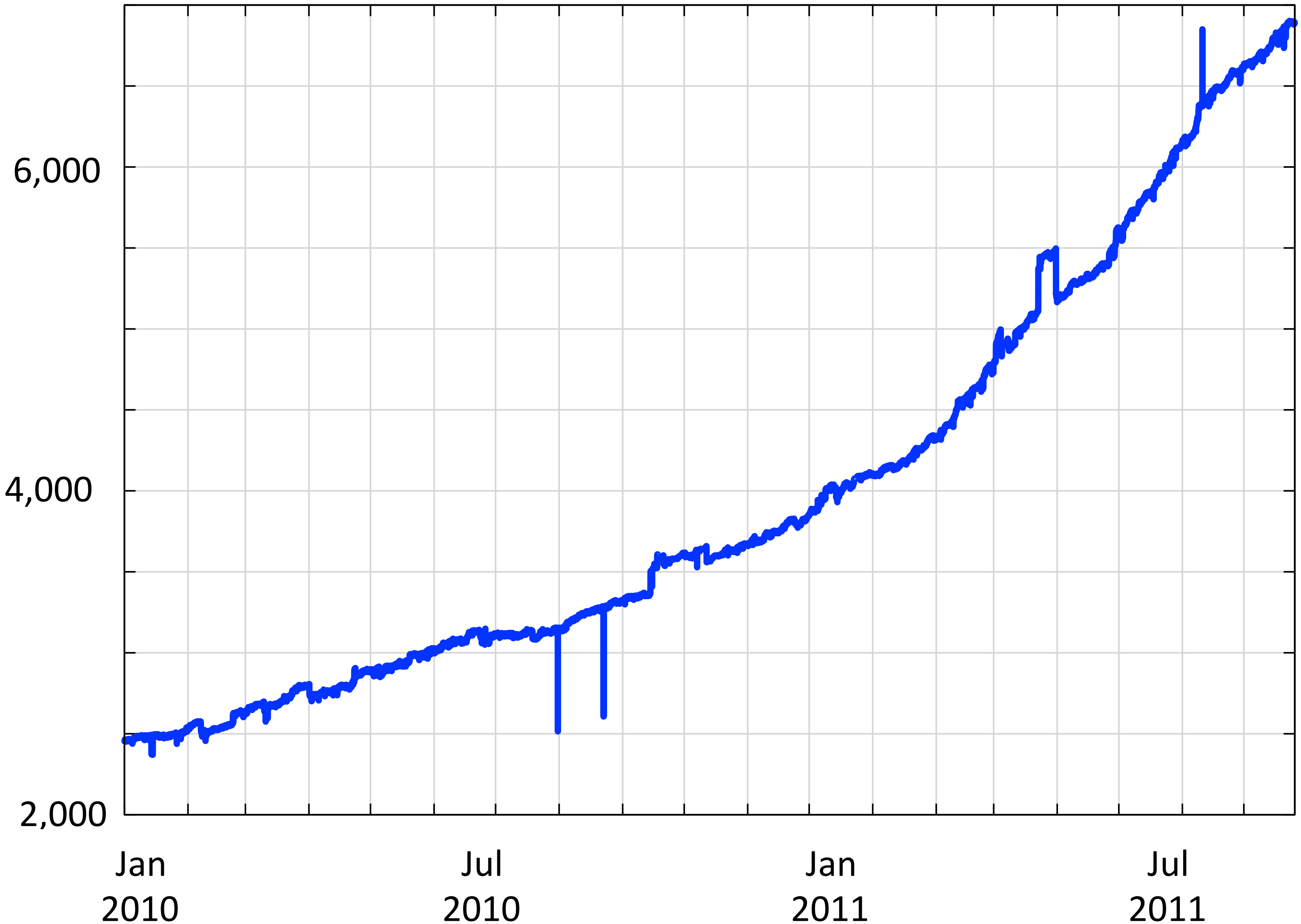
IPv4 2010 BGP Vital Statistics

	Jan-11	Oct-11	
Prefix Count	341,000	379,000	+14%
Roots	168,000	185,000	+13%
More Specifics	173,000	192,000	+15%
Address Span	140/8s	148/8s	+ 7%
AS Count	36,400	39,000	+10%
Transit	5,000	5,400	+ 9%
Stub	31,400	33,600	+ 10%

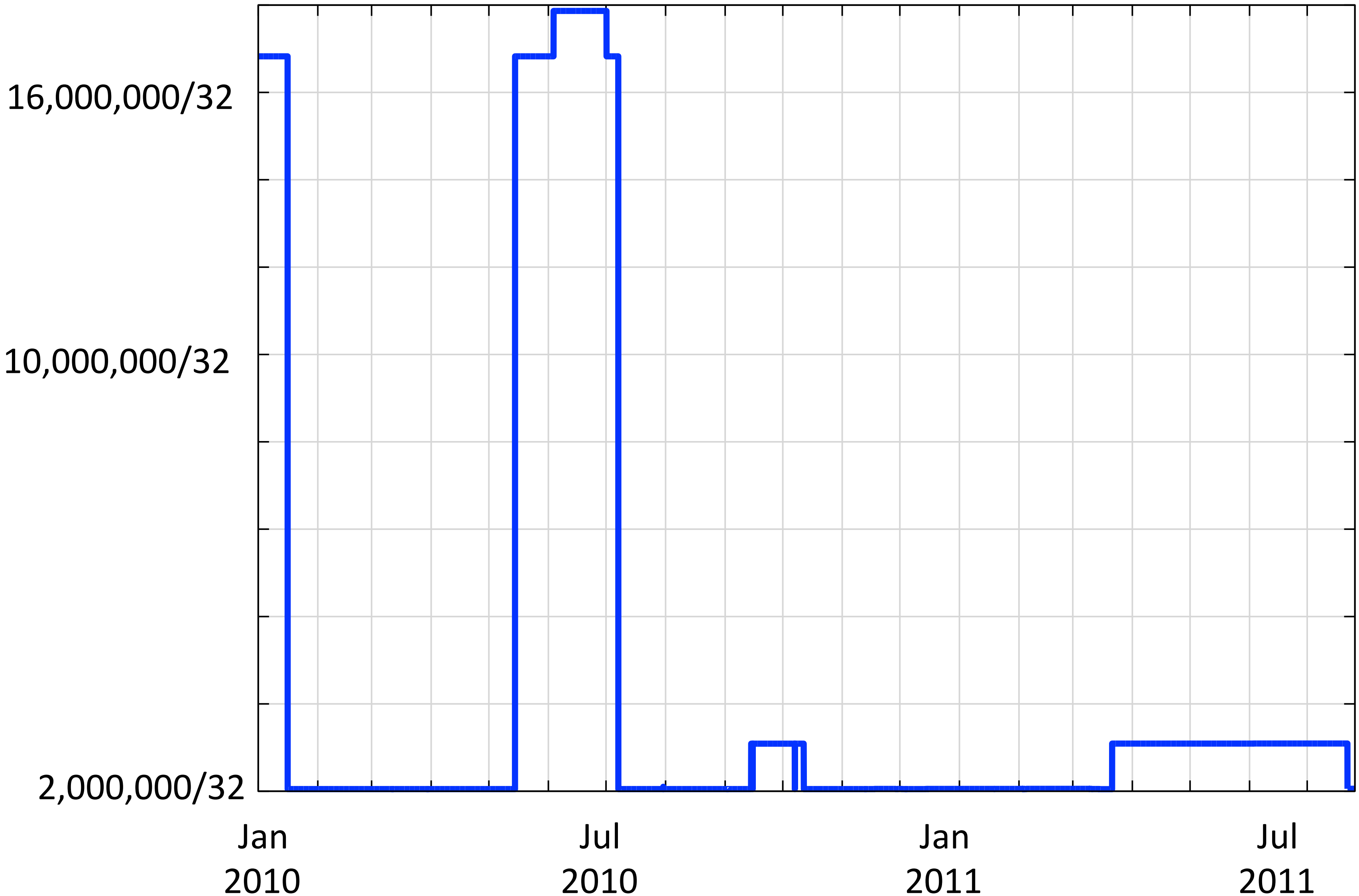
IPv4 in 2011

- Overall Internet growth in terms of BGP is at a rate of some ~12% p.a.
  - This is much the same as 2009 and 2010.
- Table growth has slowed since 20 April 2011, following APINC's IPv4 address run out
- Address span growing more slowly than the table size (address consumption pressures evident?)

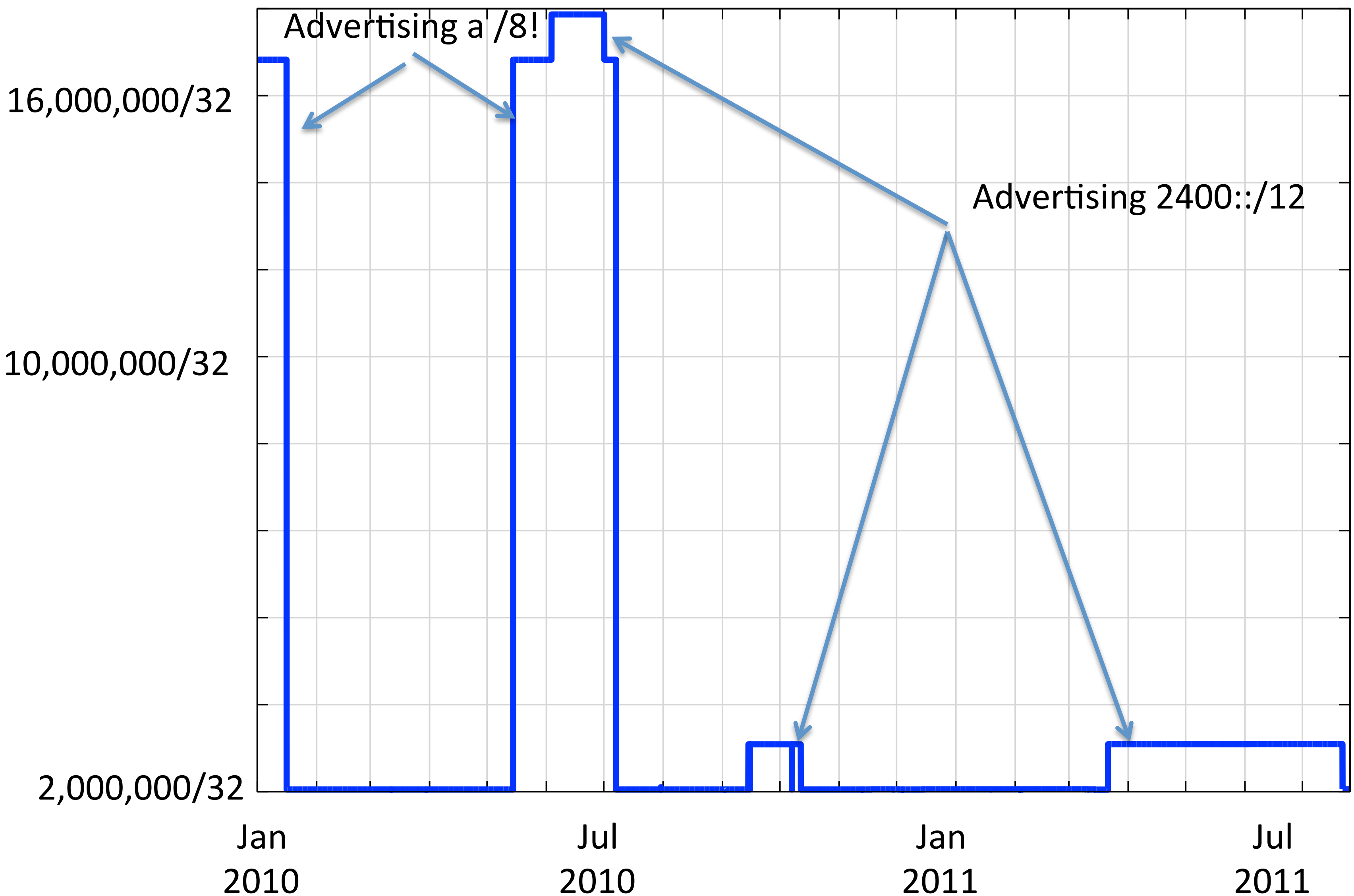
IPv6 BGP Prefix Count



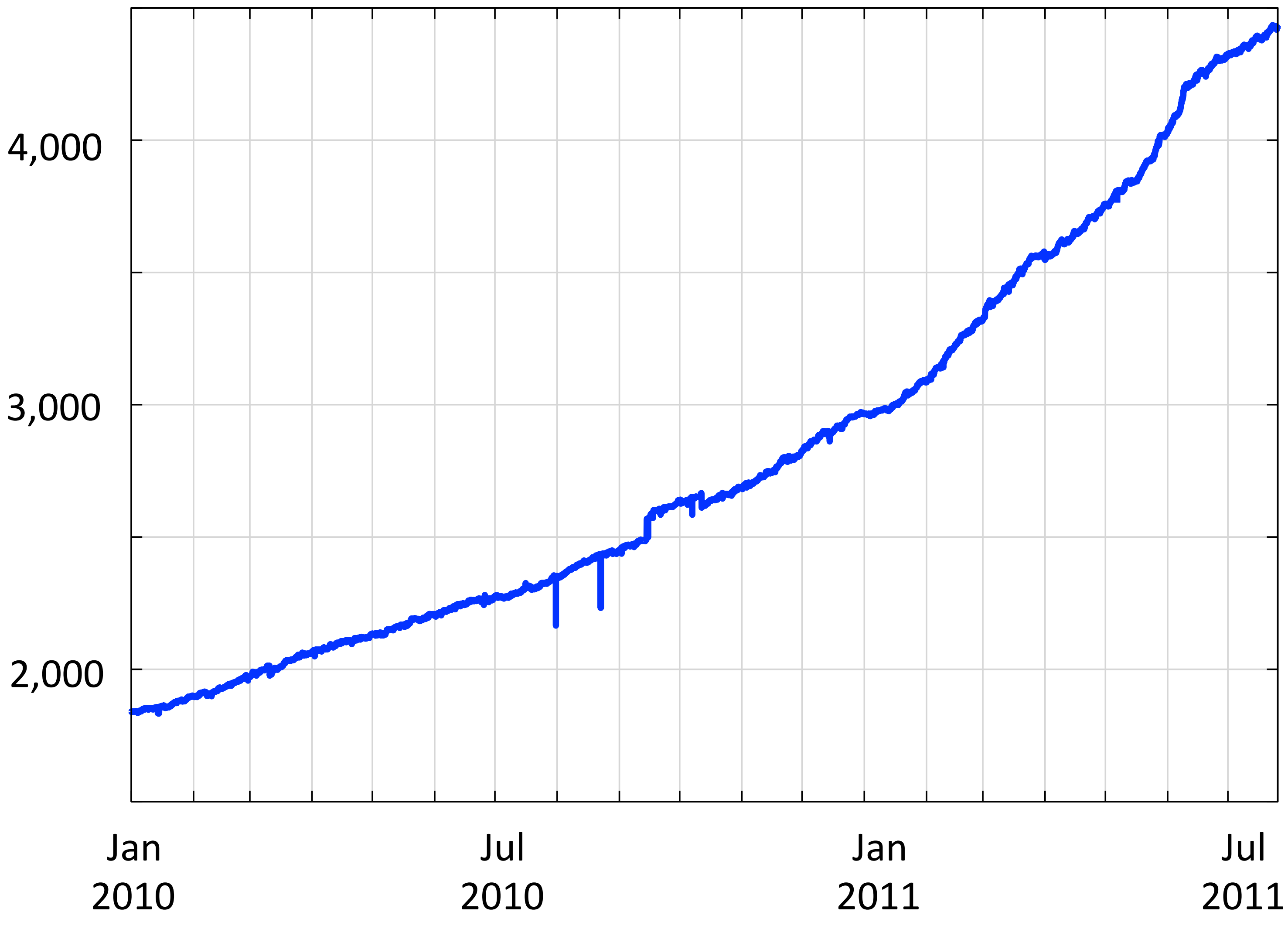
IPv6 Routed Address Span



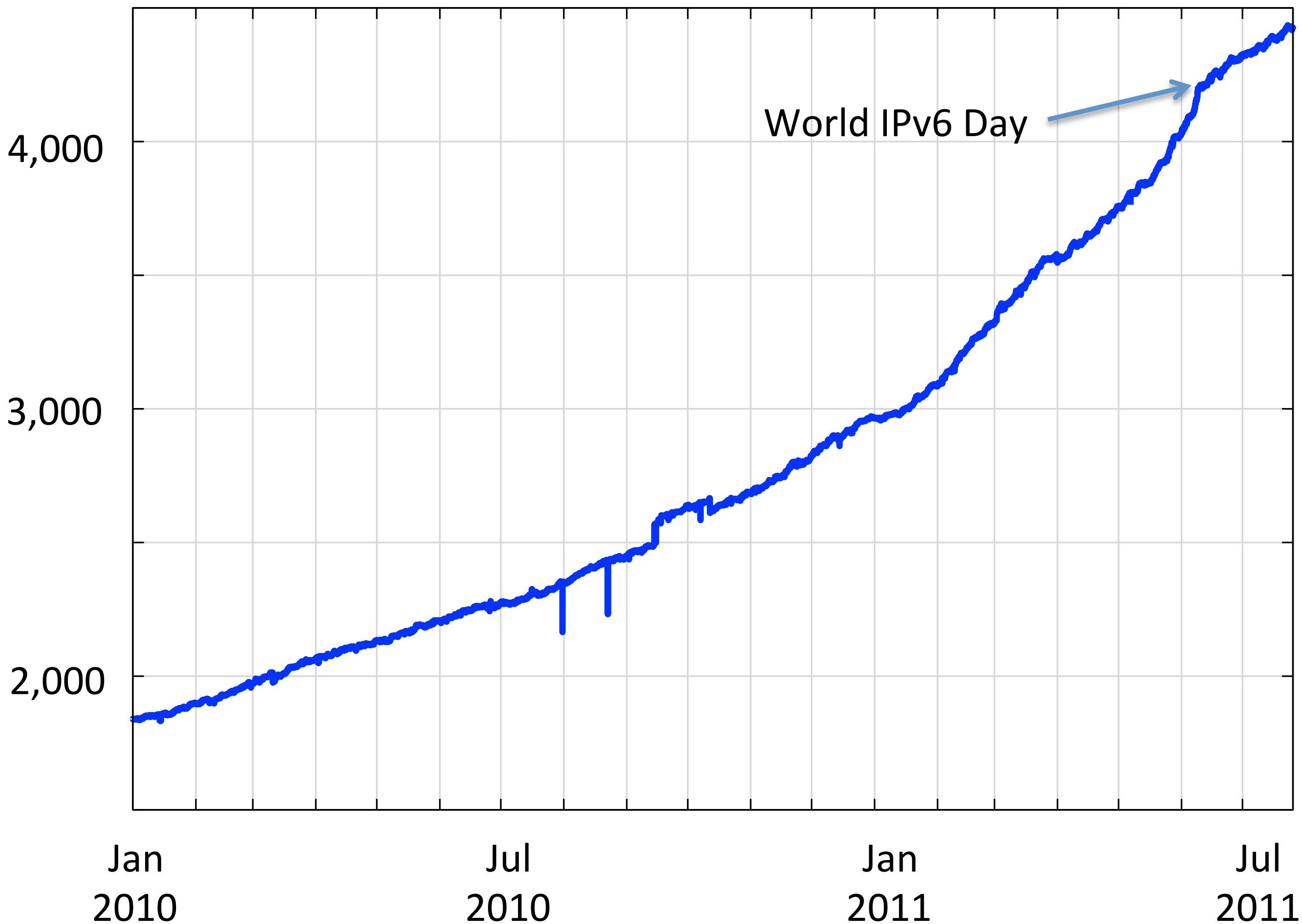
IPv6 Routed Address Span



IPv6 Routed AS Count



IPv6 Routed AS Count



IPv6 2011 BGP Vital Statistics

	Jan-10	Jan-11	Jul-11	p.a. rate
Prefix Count	2,458	4,100	6,889	**+ 117%**
Roots	1,965	3,178	5,090	+ 103%
More Specifics	494	922	1,799	+ 163%
Address Span (/32s)	48,559	53,415	56,561	**+ 10%**
AS Count	1,839	2,966	4,424	**+ 84%**
Transit	348	556	808	+ 78%
Stub	1,437	2,343	3,549	+ 88%

IPv6 in 2010 - 2011

- Overall IPv6 Internet growth in terms of BGP is 80% - 120 % p.a.
  - 2009 growth rate was ~ 50%.

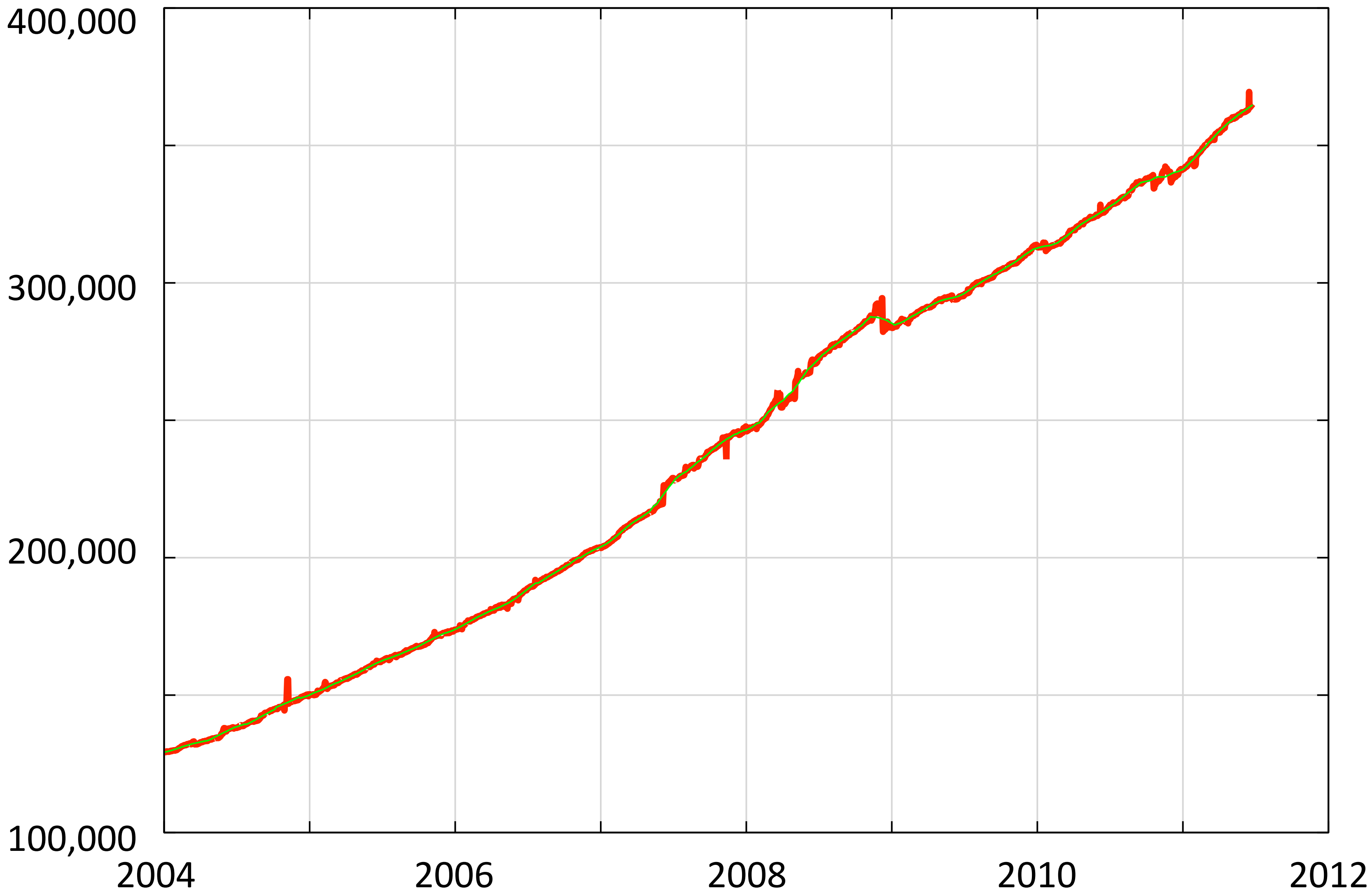
(Looking at the AS count, if these relative growth rates persist then the IPv6 network would span the same network domain as IPv4 in 5 years time -- mid/late 2016)

BGP Size Projections

- Generate a projection of the IPv4 routing table using a quadratic (O(2) polynomial) over the historic data
  - For IPv4 this is a time of **extreme uncertainty**
    - Registry IPv4 address run out
    - Uncertainty over the impacts of any after-market in IPv4 on the routing table

which makes this projection even more speculative than normal!

IPv4 Table Size



Daily Growth Rates

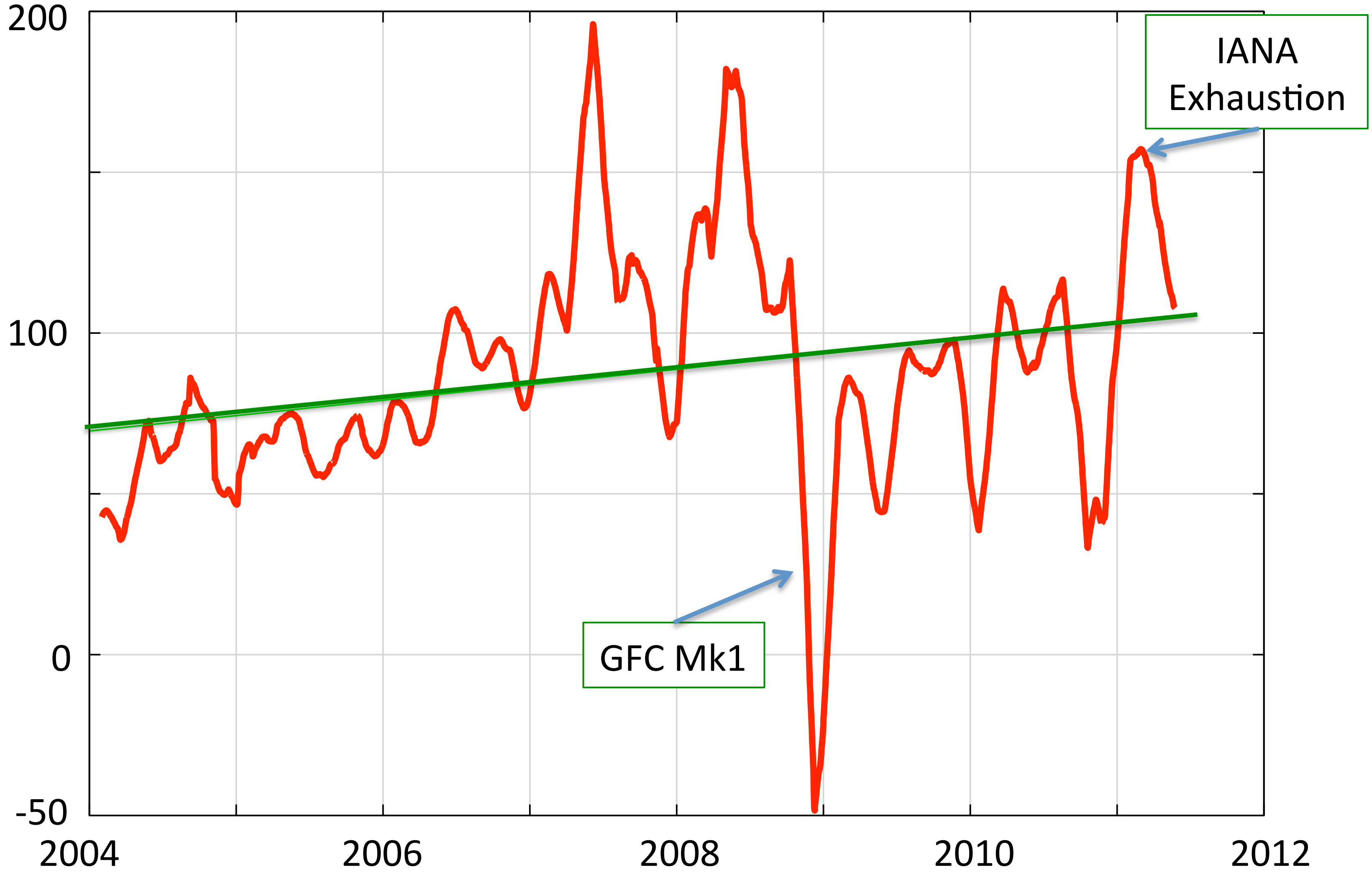
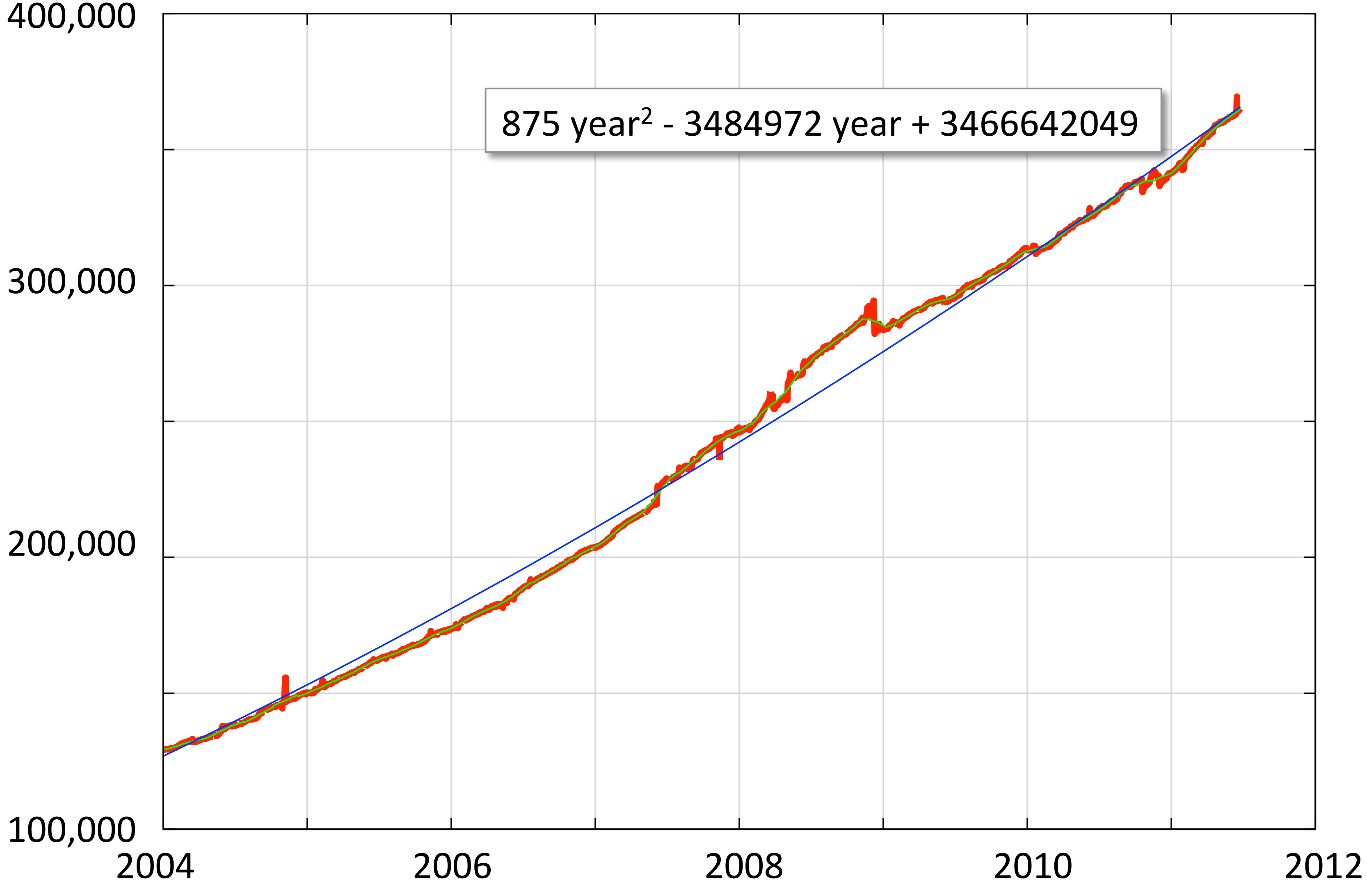
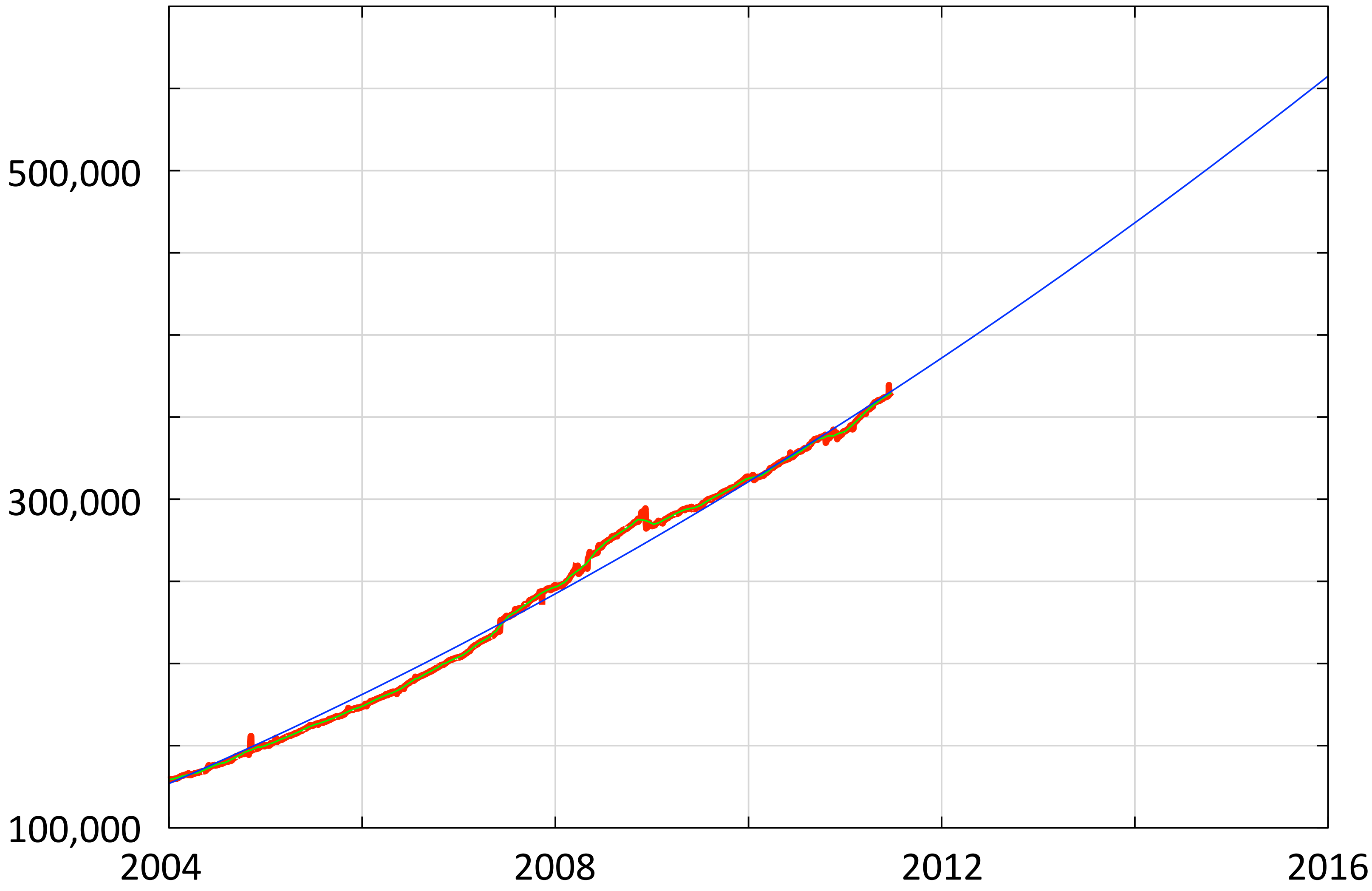


Table Growth Model



IPv4 Table Projection

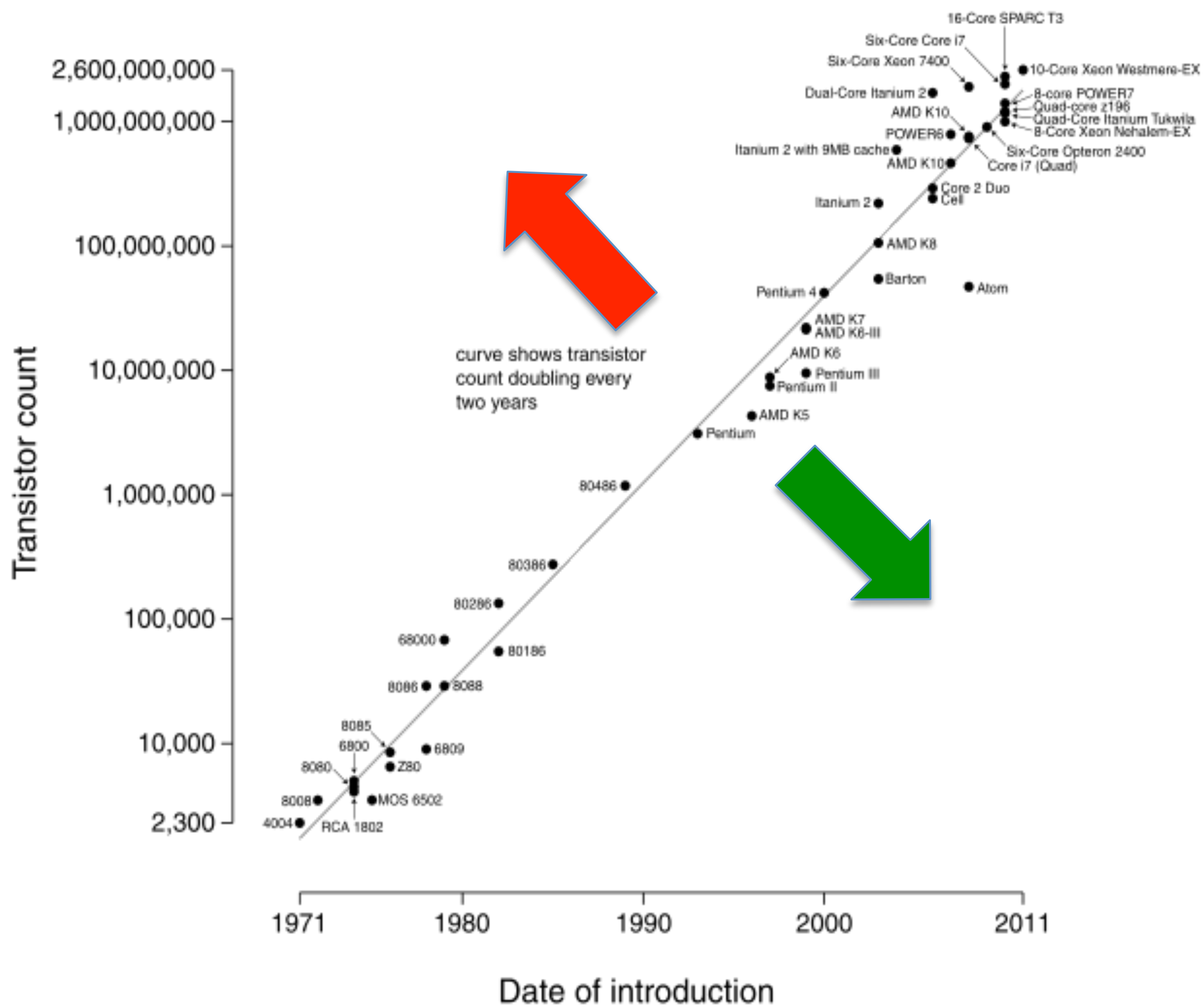


Up and to the Right

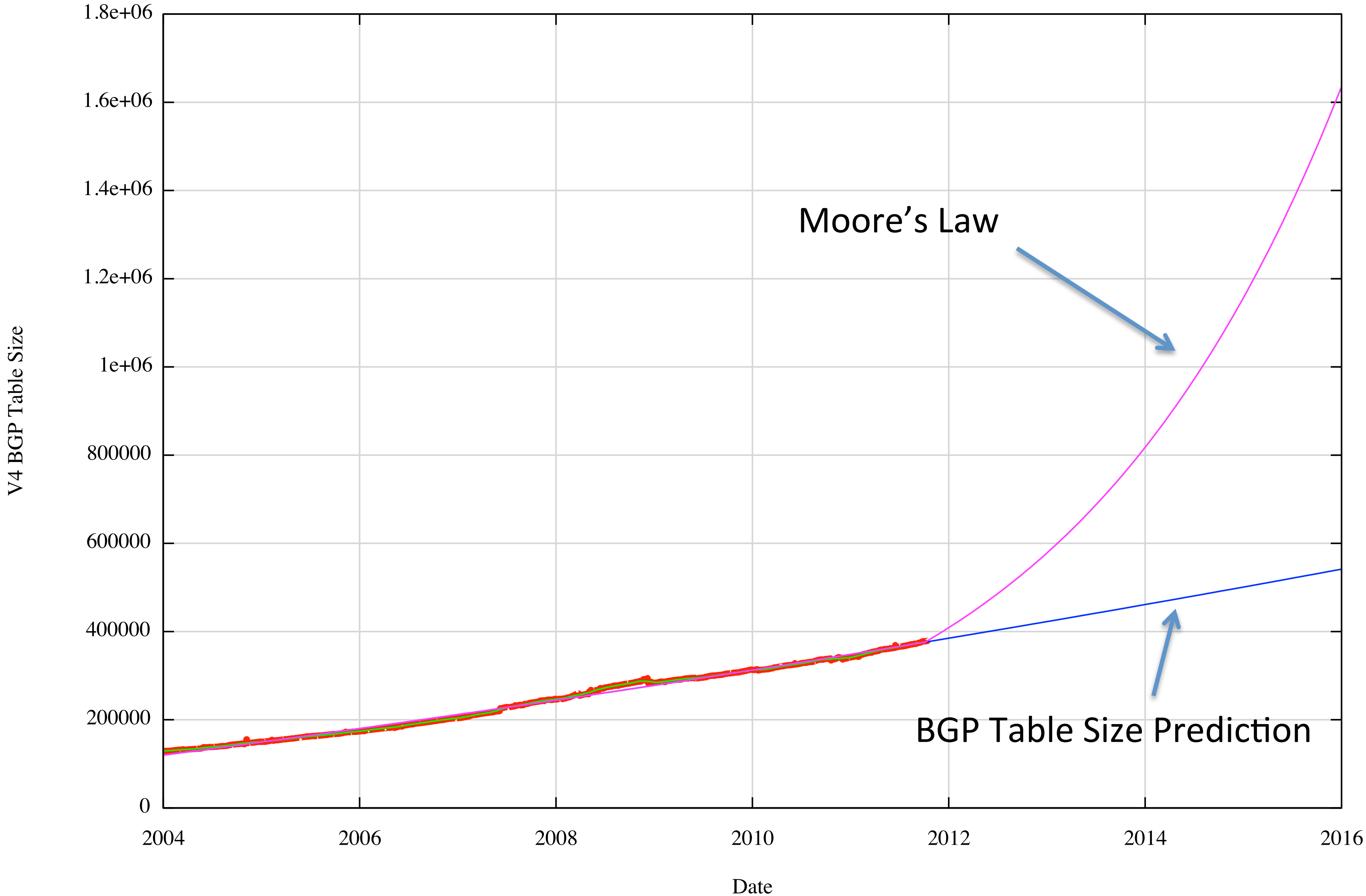
- Most Internet curves (except the adoption of IPv6) are "up and to the right"
- But what makes this curve painful?

Moore's Law!

Microprocessor Transistor Counts 1971-2011 & Moore's Law



IPv4 BGP Table size and Moore's Law

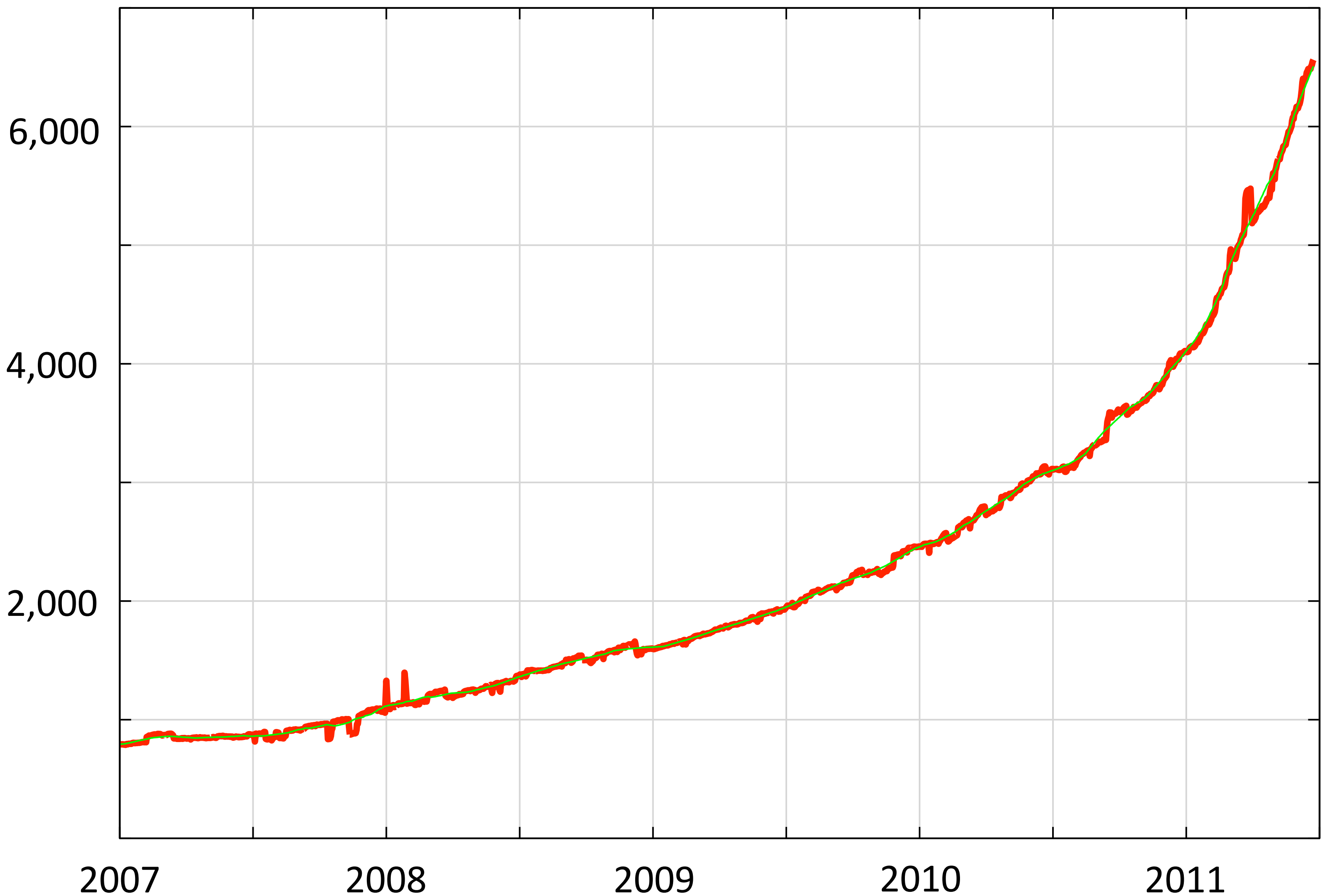


IPv4 BGP Table Size predictions

Jan 2011	347,000 entries
2012*	385,000 entries
2013*	426,000 entries
2014*	468,000 entries
2015*	512,000 entries
2016*	557,000 entries

* *These numbers are dubious due to uncertainties introduced by IPv4 address exhaustion pressures.*

IPv6 Table Size



Daily Growth Rates

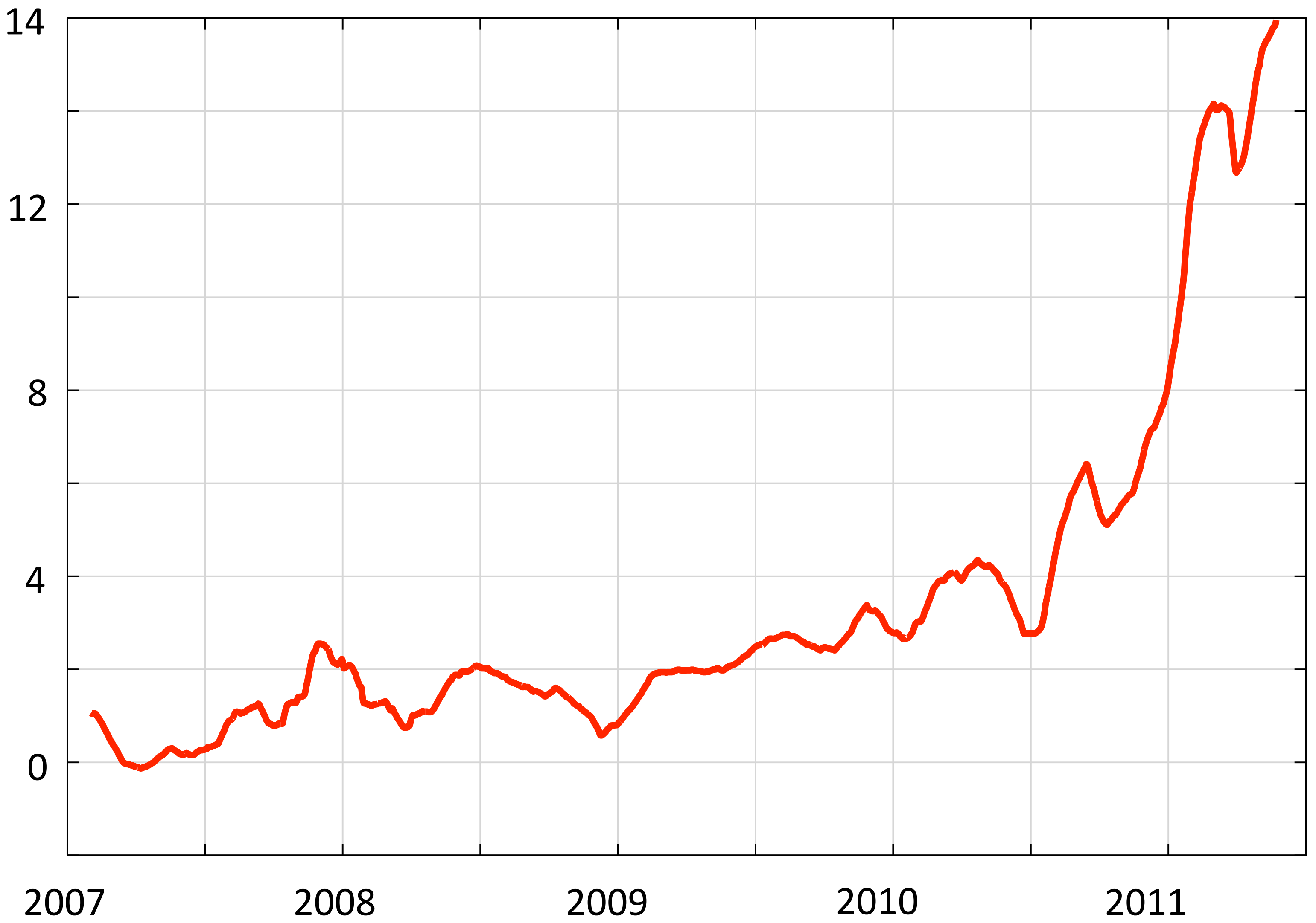
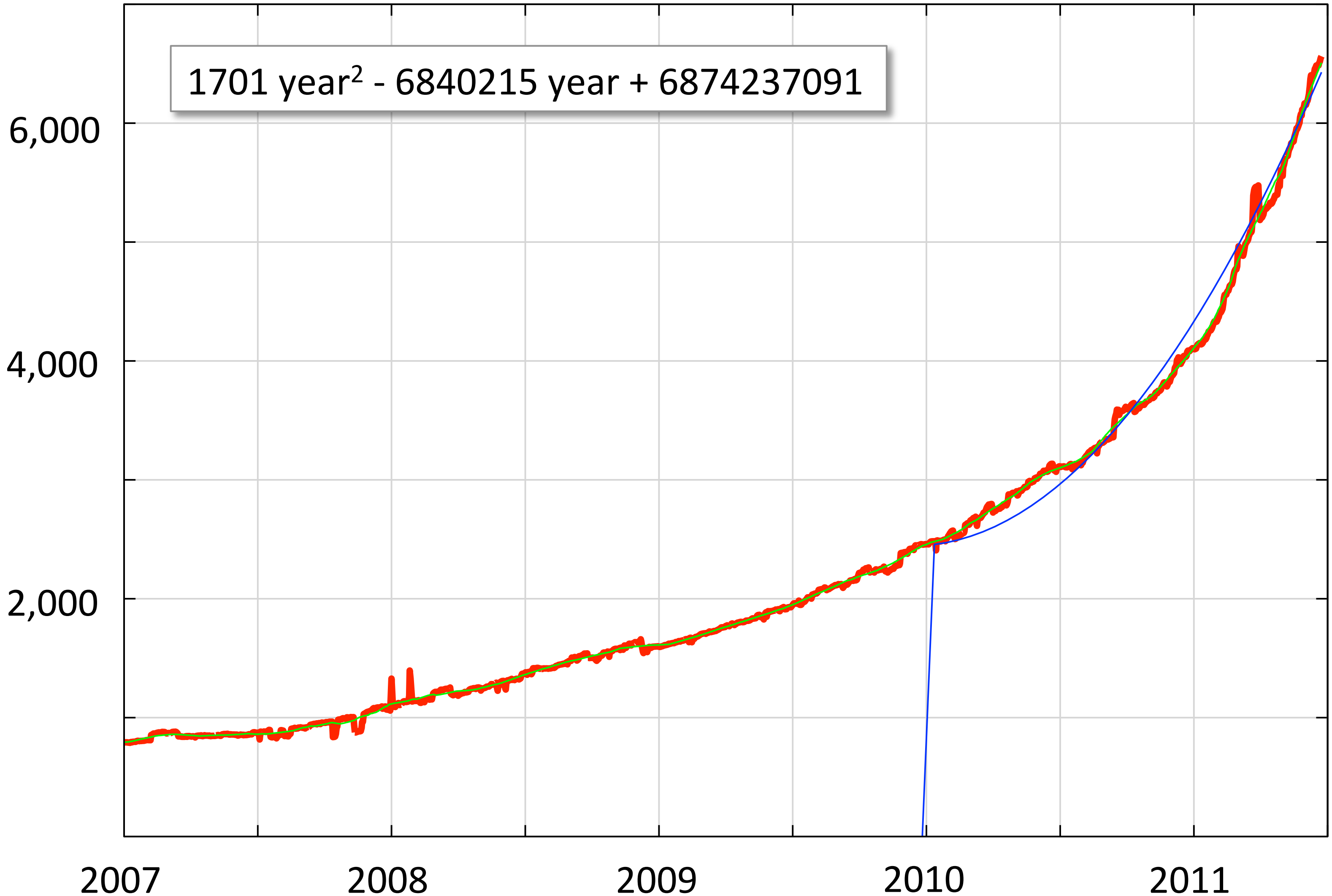
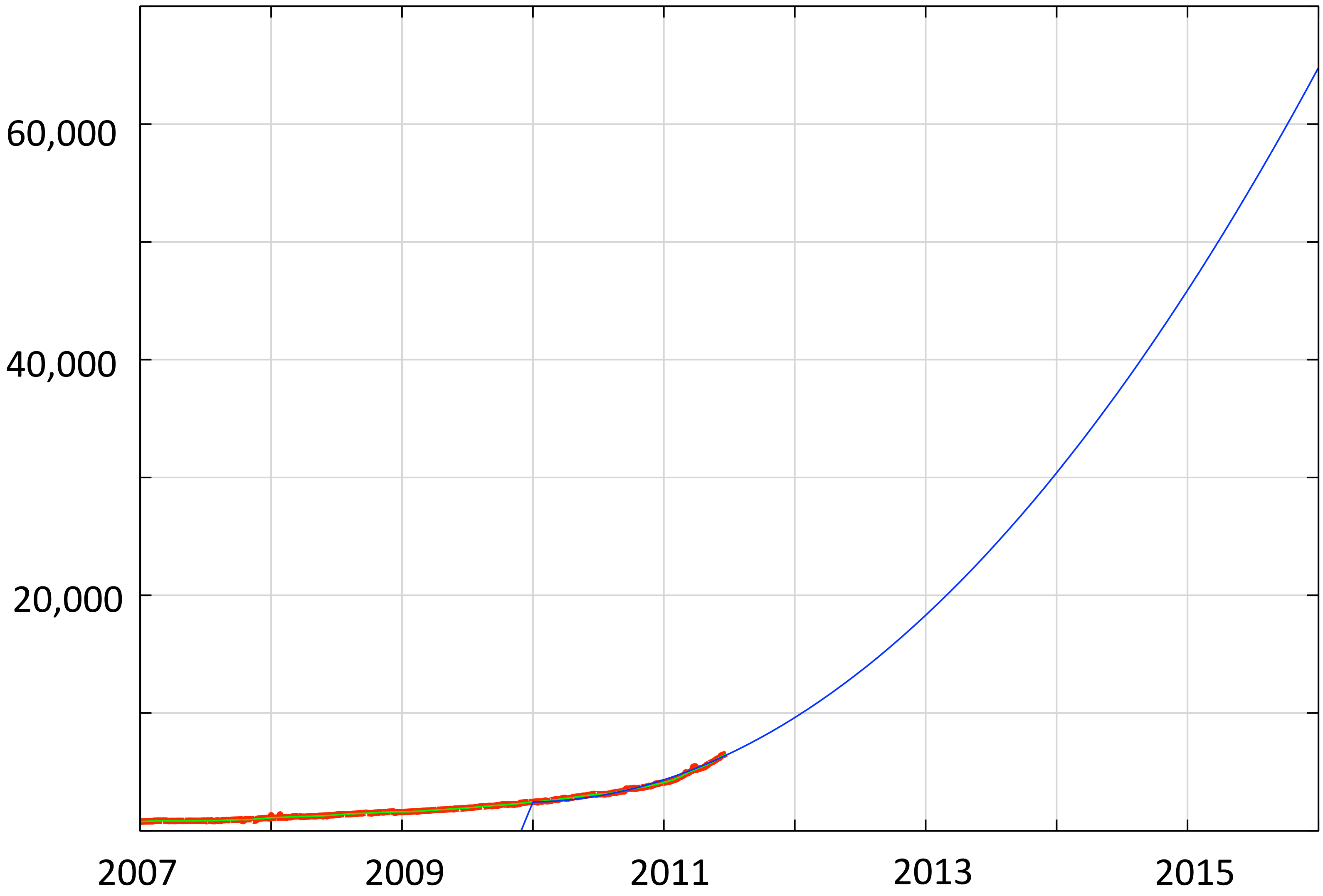


Table Growth Model



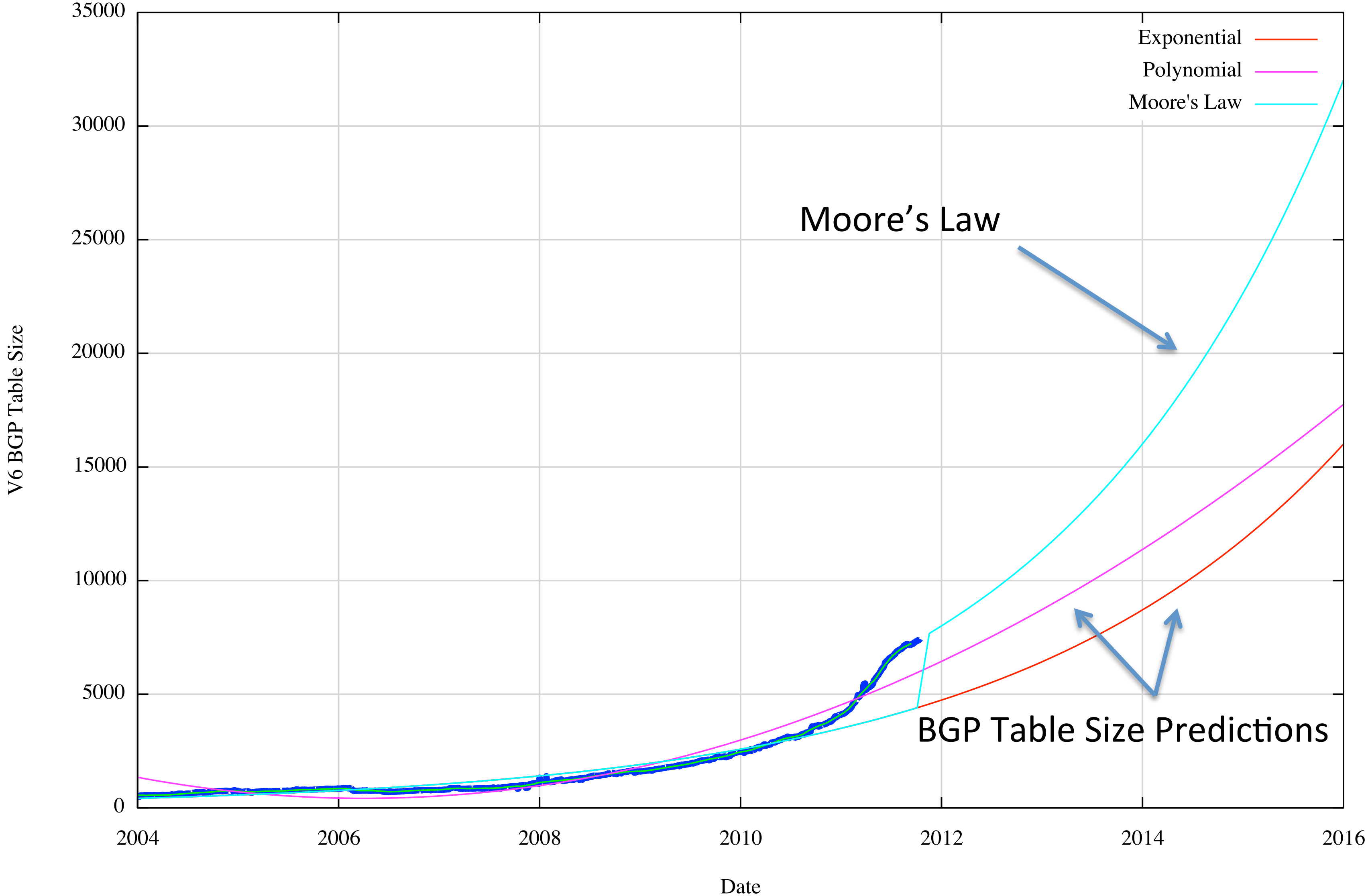
IPv6 Table Projection



IPv6 BGP Table Size predictions

Jan 2011	4,000 entries
2012	10,000 entries
2013	18,000 entries
2014	30,000 entries
2015	46,000 entries
2016	65,000 entries

IPv6 Projections and Moore's Law



BGP Table Size Predictions

Jan 2011	$347{,}000_4$ + $4{,}000_6$ entries
2012	$385{,}000_4$ + $10{,}000_6$ entries
2013*	$426{,}000_4$ + $18{,}000_6$ entries
2014*	$468{,}000_4$ + $30{,}000_6$ entries
2015*	$512{,}000_4$ + $46{,}000_6$ entries
2016*	$557{,}000_4$ + $65{,}000_6$ entries

* *These numbers are dubious due to IPv4 address exhaustion pressures. It is possible that the number will be larger than the values predicted by this model.*

Is This a Problem?

Is This a Problem?

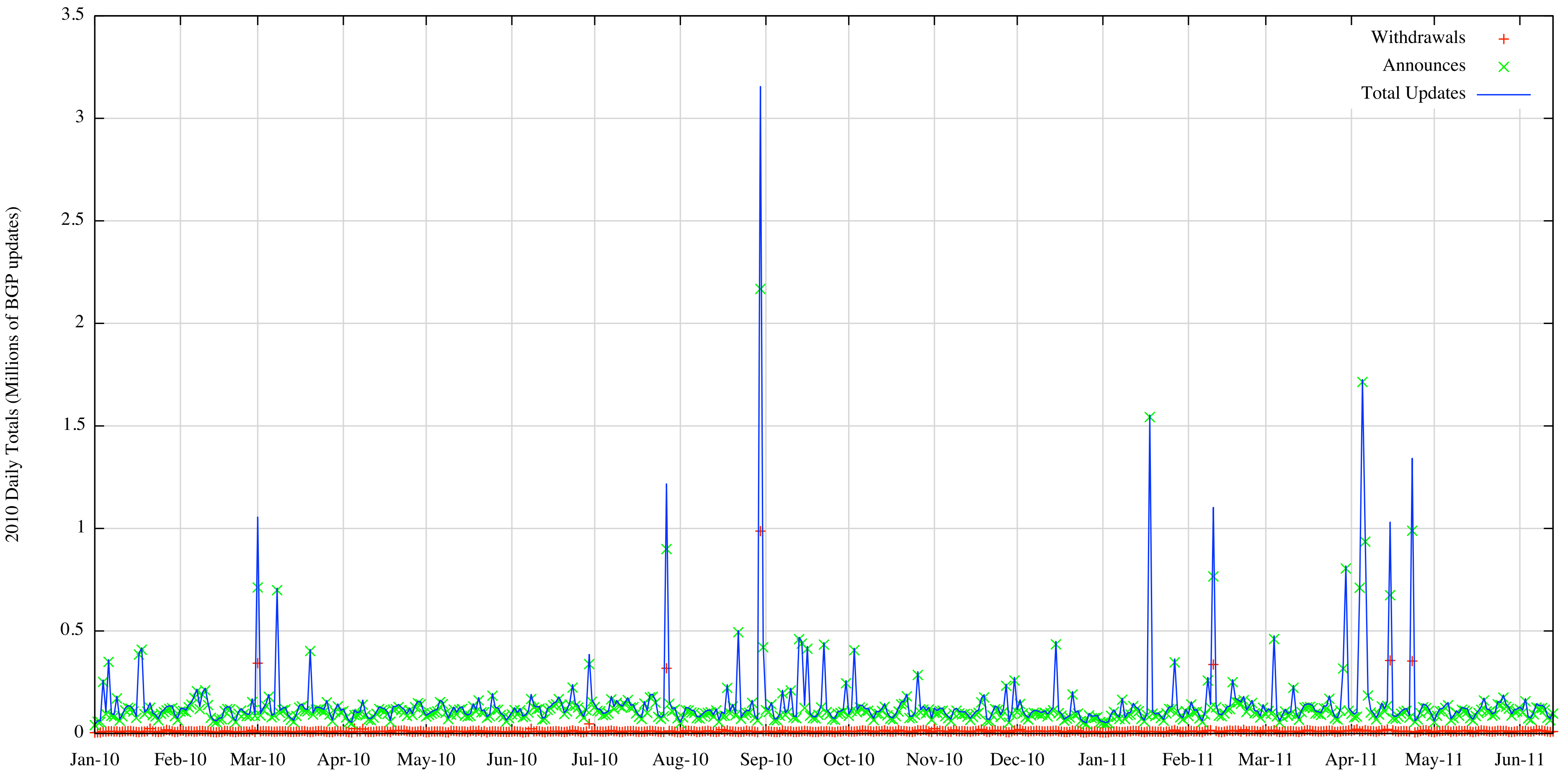
- What is the anticipated end of service life of your core routers?
- What's the price/performance curve for forwarding engine ASICS?
- What's a sustainable growth factor in FIB size that will allow for continued improvement in unit costs of routing?
- What is a reasonable margin of uncertainty in these projections?

Does Size REALLY matter?

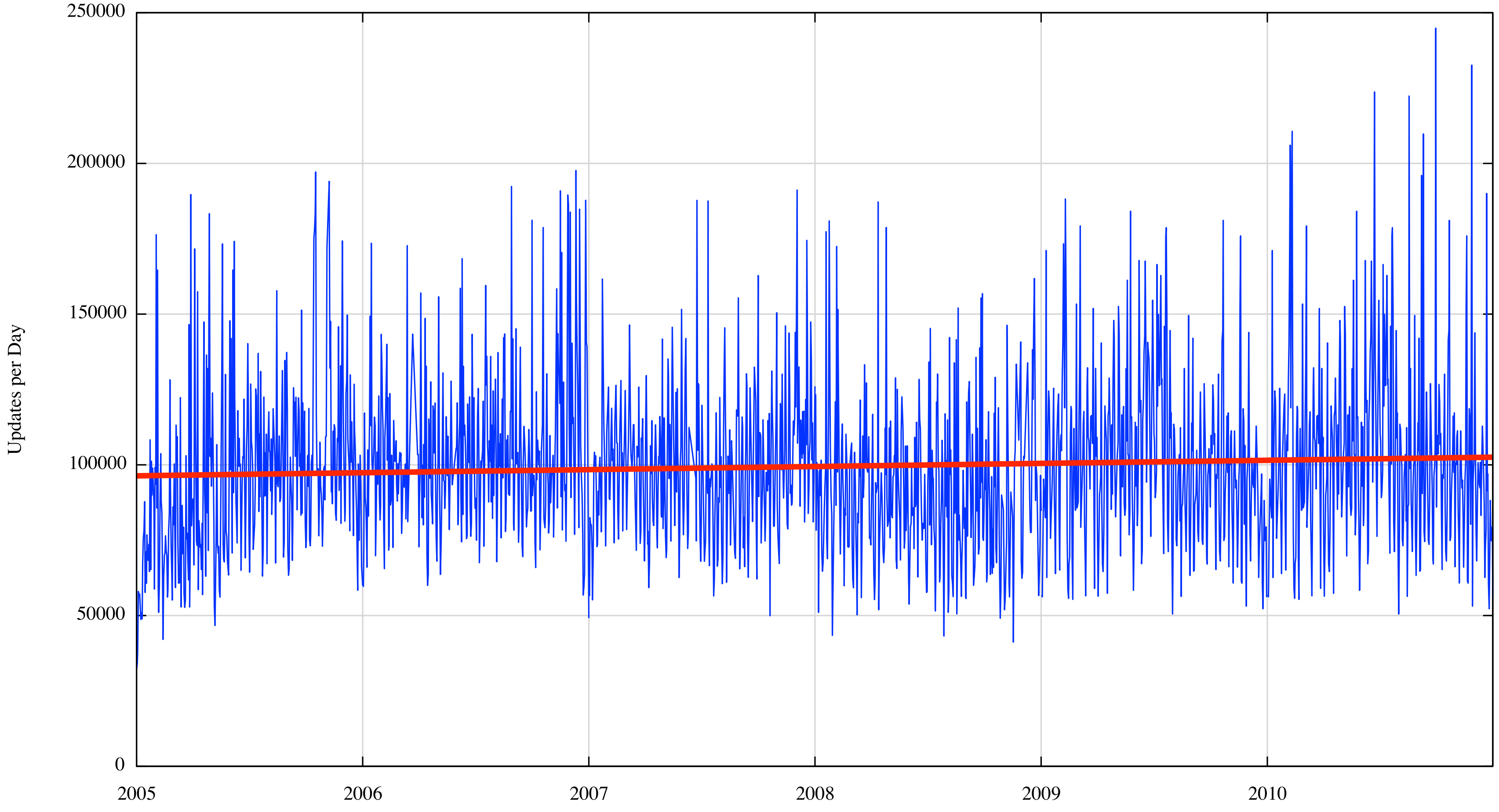
Is it the **size of the RIB** or the **level of dynamic update and routing stability** that is the concern here?

So lets look at update trends in BGP…

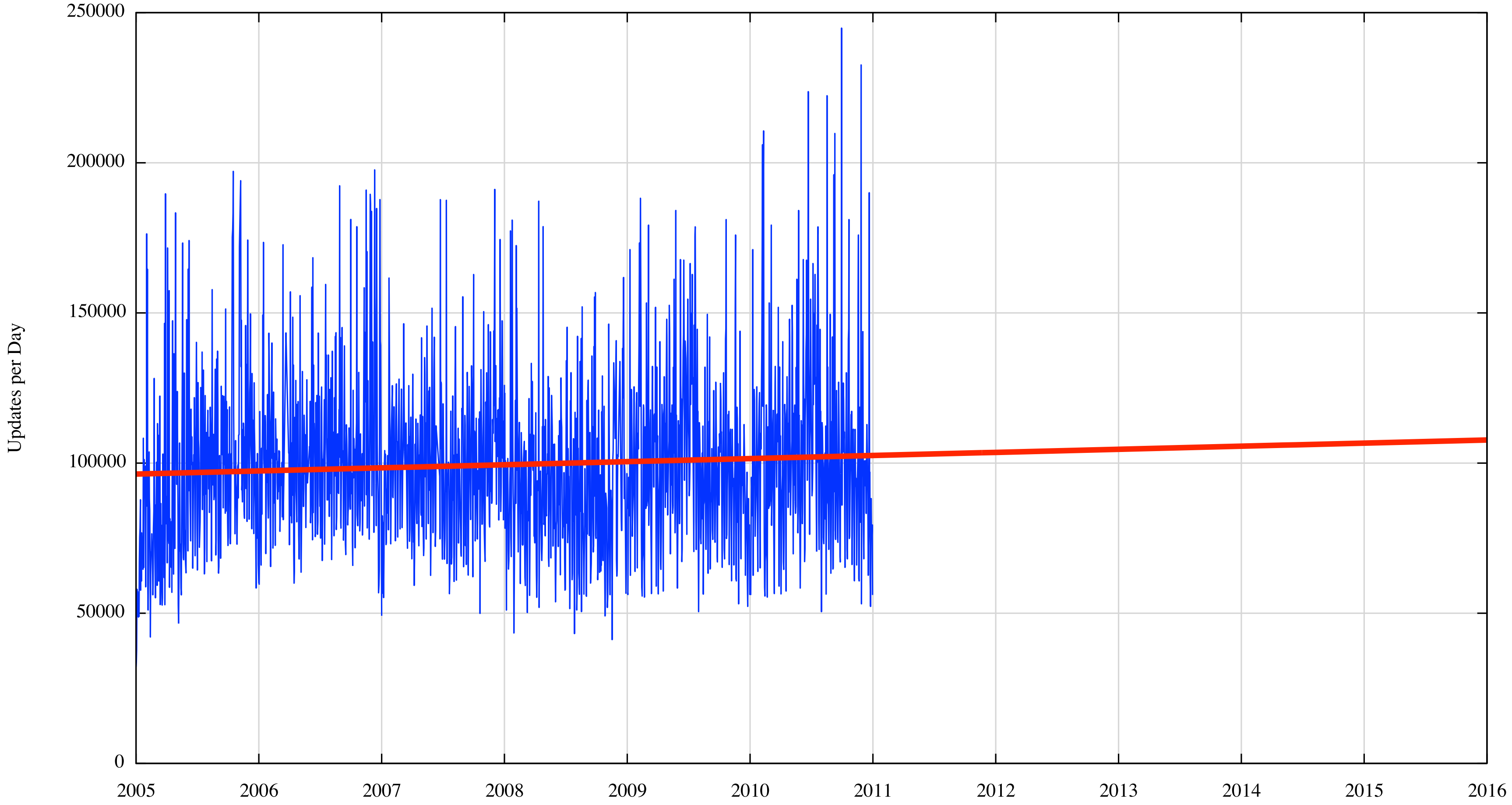
Daily Announce and Withdrawal Rates



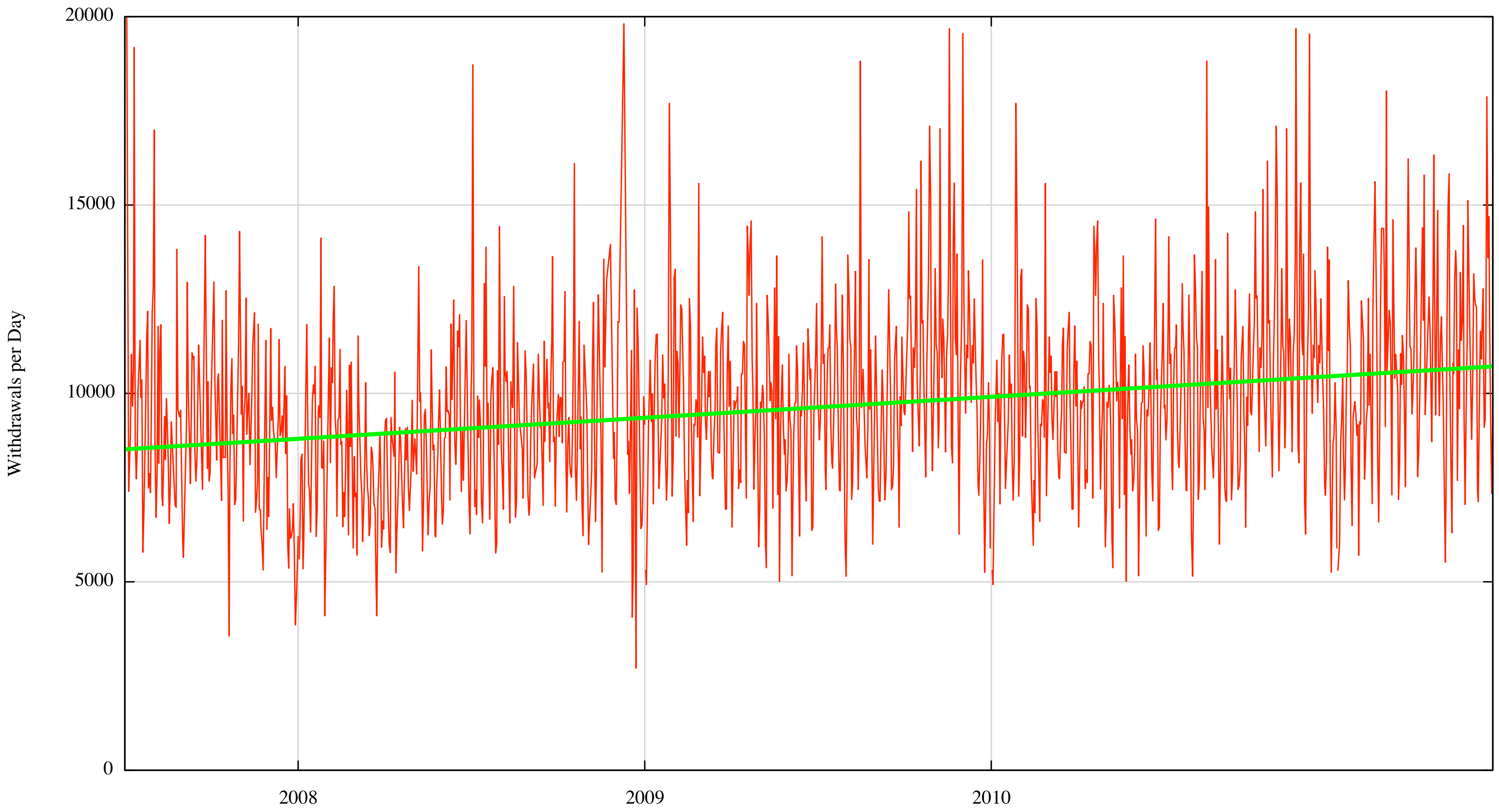
Updates – Extended Data Set



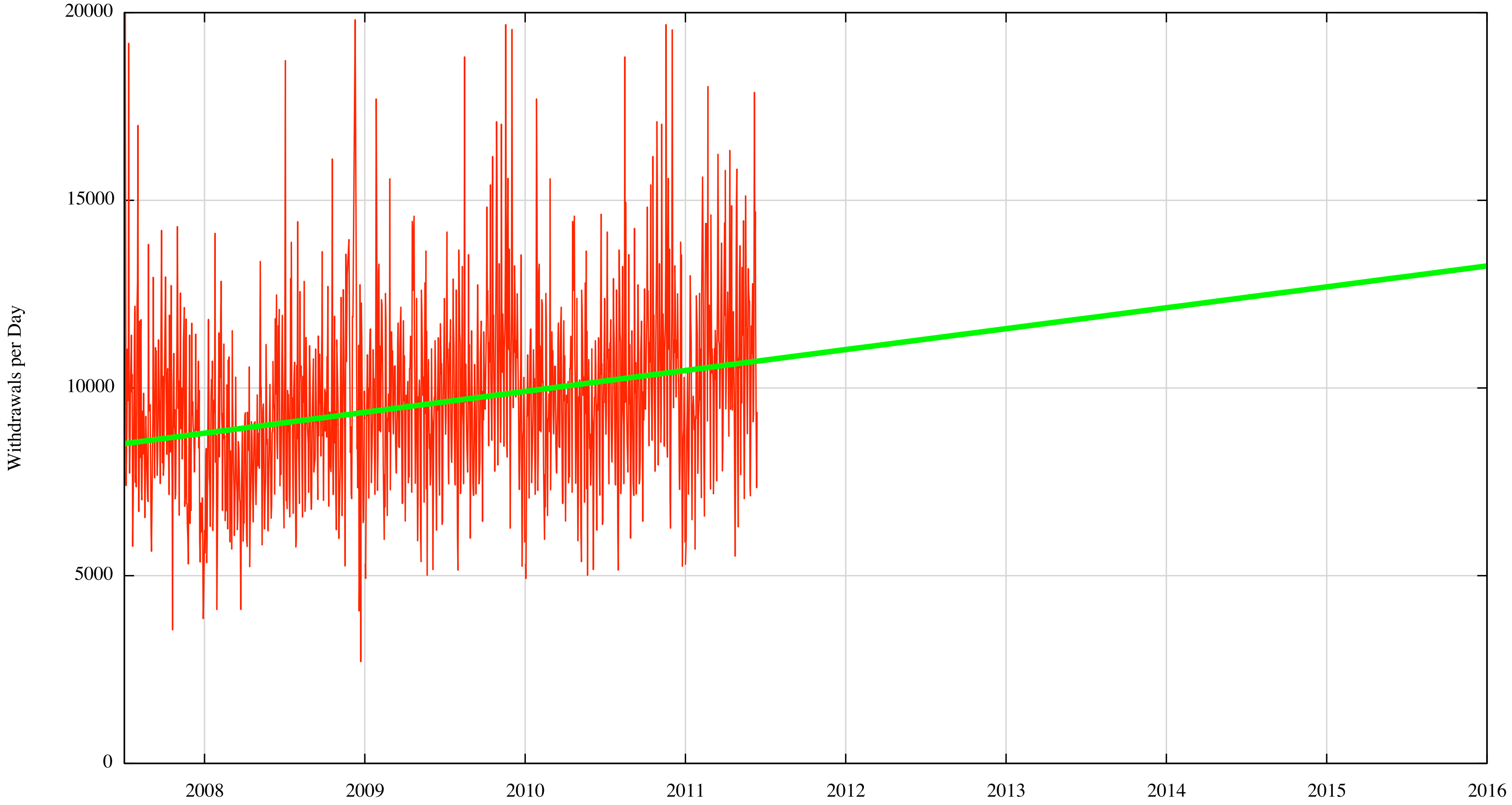
Daily Update Rate – Linear Projection



Withdrawals – Extended Data Set

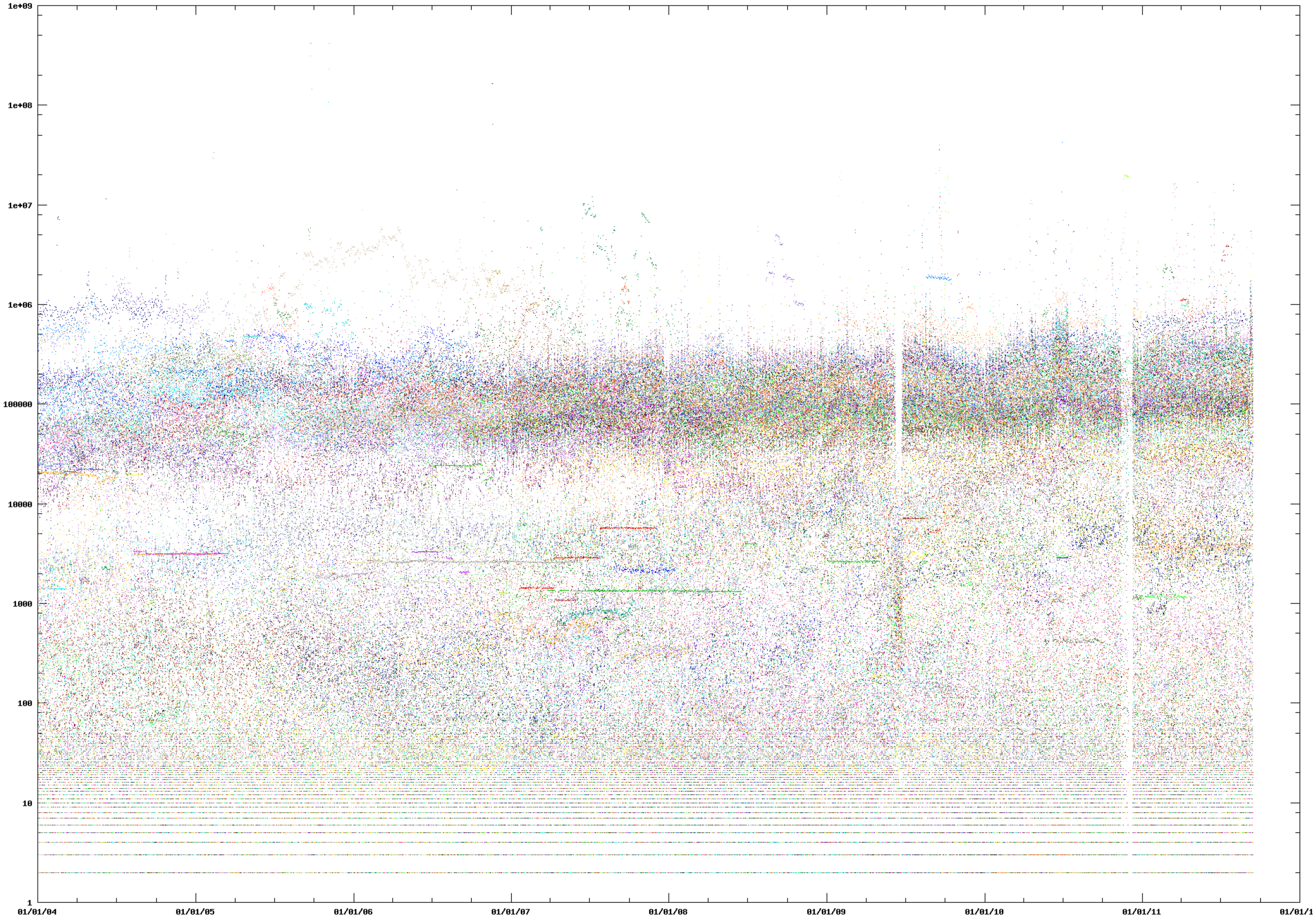


Daily Withdrawal Rate – Linear Projection

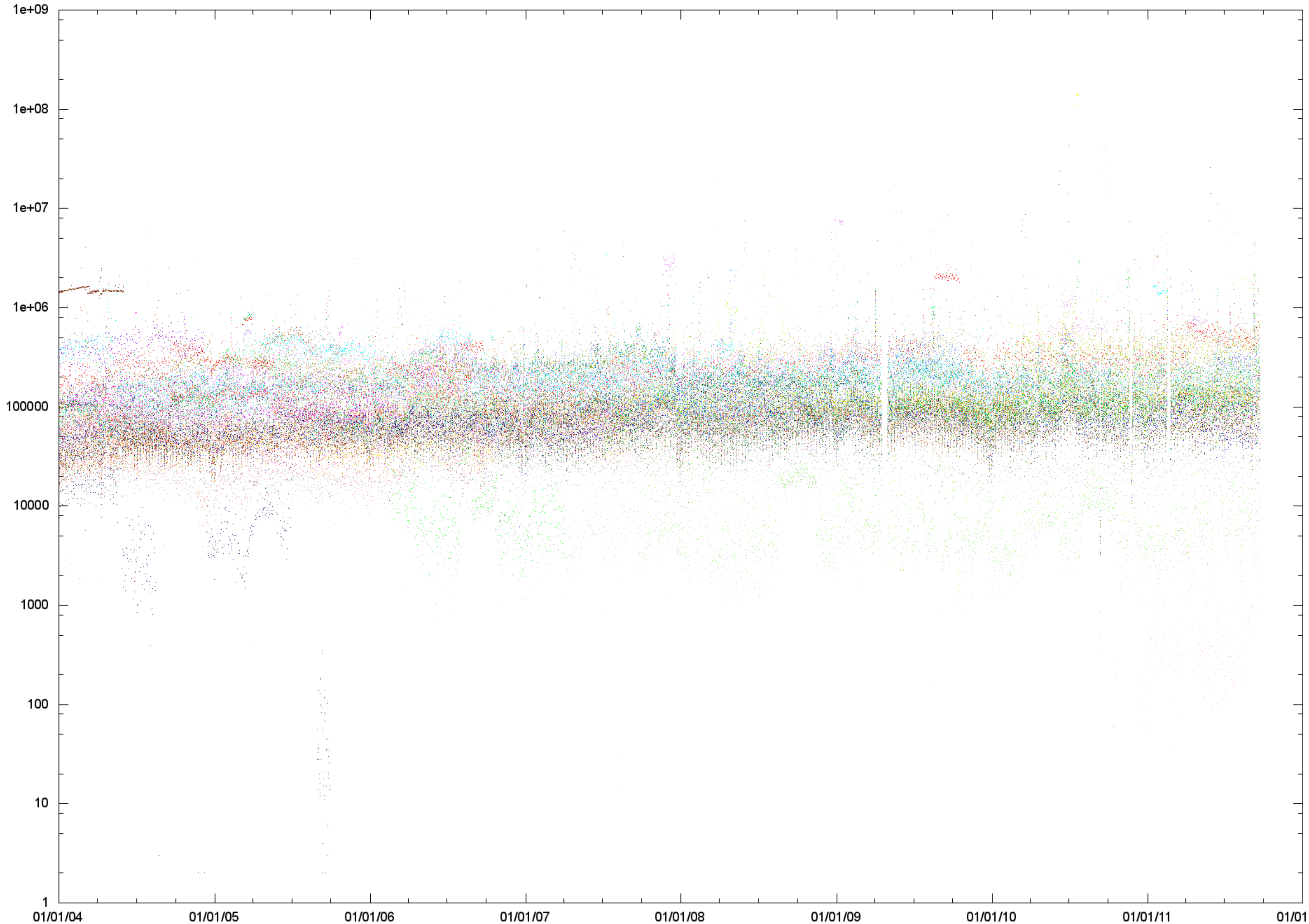


Is this just me? Or is this visible everywhere?

- So I looked at all the peers of RIS and Route Views



Daily Update rate for RIS peers – 2004 to 2011



Daily Update rate for Route Views peers – 2004 to 2011

Is this just me? Or is this visible everywhere?

- It’s not me
- It’s everywhere
  - The long term growth rate of the dynamic activity of eBGP is far lower than the growth rate of the default-free routing table.

Why is the world so flat?

- An intuitive model of BGP updated would see instability as being related to the number of entries and the density of interconnectivity
  - This is obviously not the model we see here
  - So why is this particular part of the Internet's BGP behaviour so anomalous?

BGP Updates

- There are two components to BGP update activity:
  1. Convergence updates as BGP searches for a new stable “solution”
  2. The update relating to the “primary” event
- In an ever expanding network both BGP update components should be rising
  - But the total number of updates is not rising
- So what is going on?

Convergence

- BGP is a distance vector protocol
- This implies that BGP may send a number of updates in a tight "cluster" before converging to the "best" path
- This is clearly evident in withdrawals and convergence to (longer) secondary paths

For Example

Withdrawal at source at 08:00:00 03-Apr of 84.205.77.0/24 at MSK-IX, as observed at AS 2.0

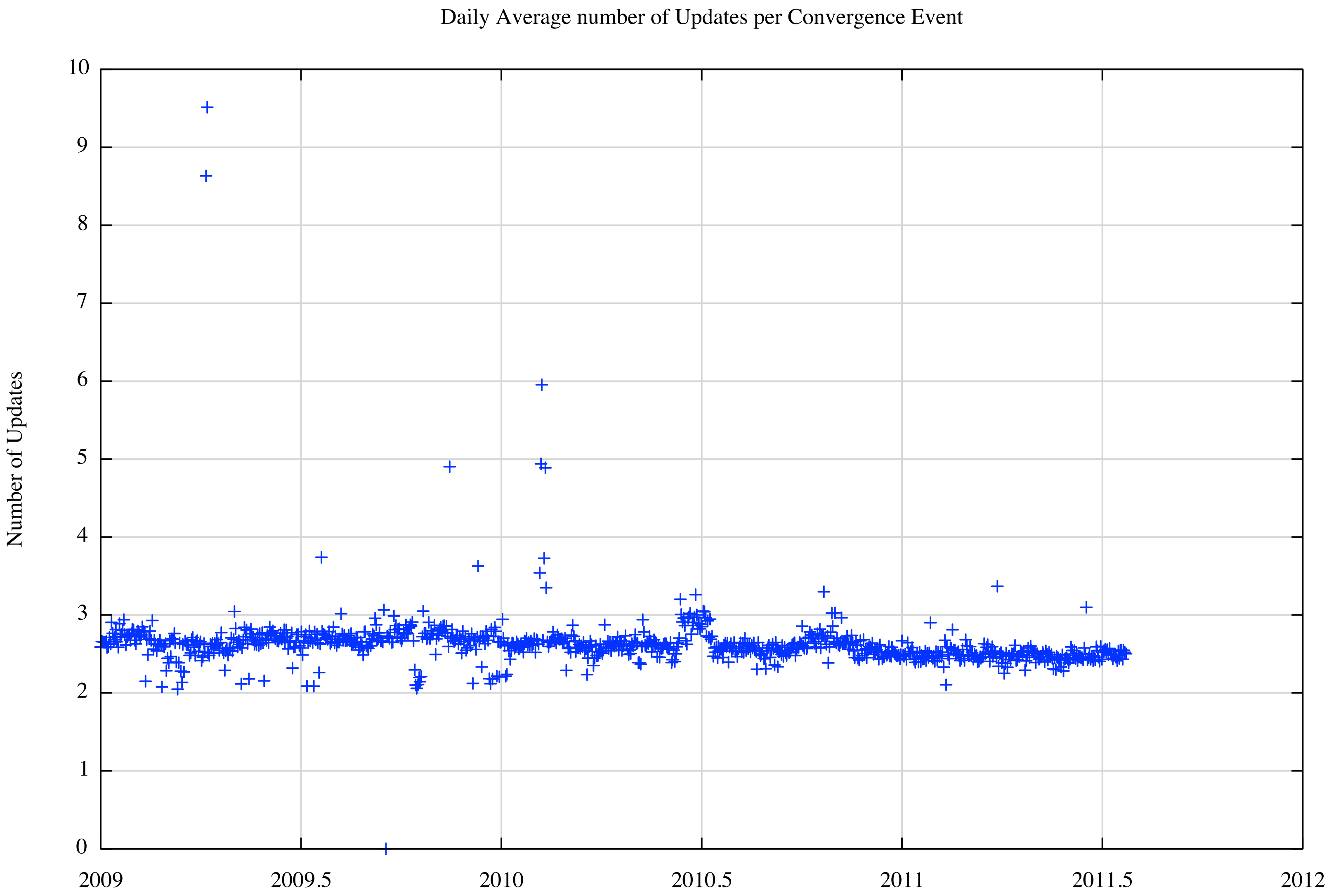
Announced AS Path: <4777 2497 9002 12654>

Received update sequence:

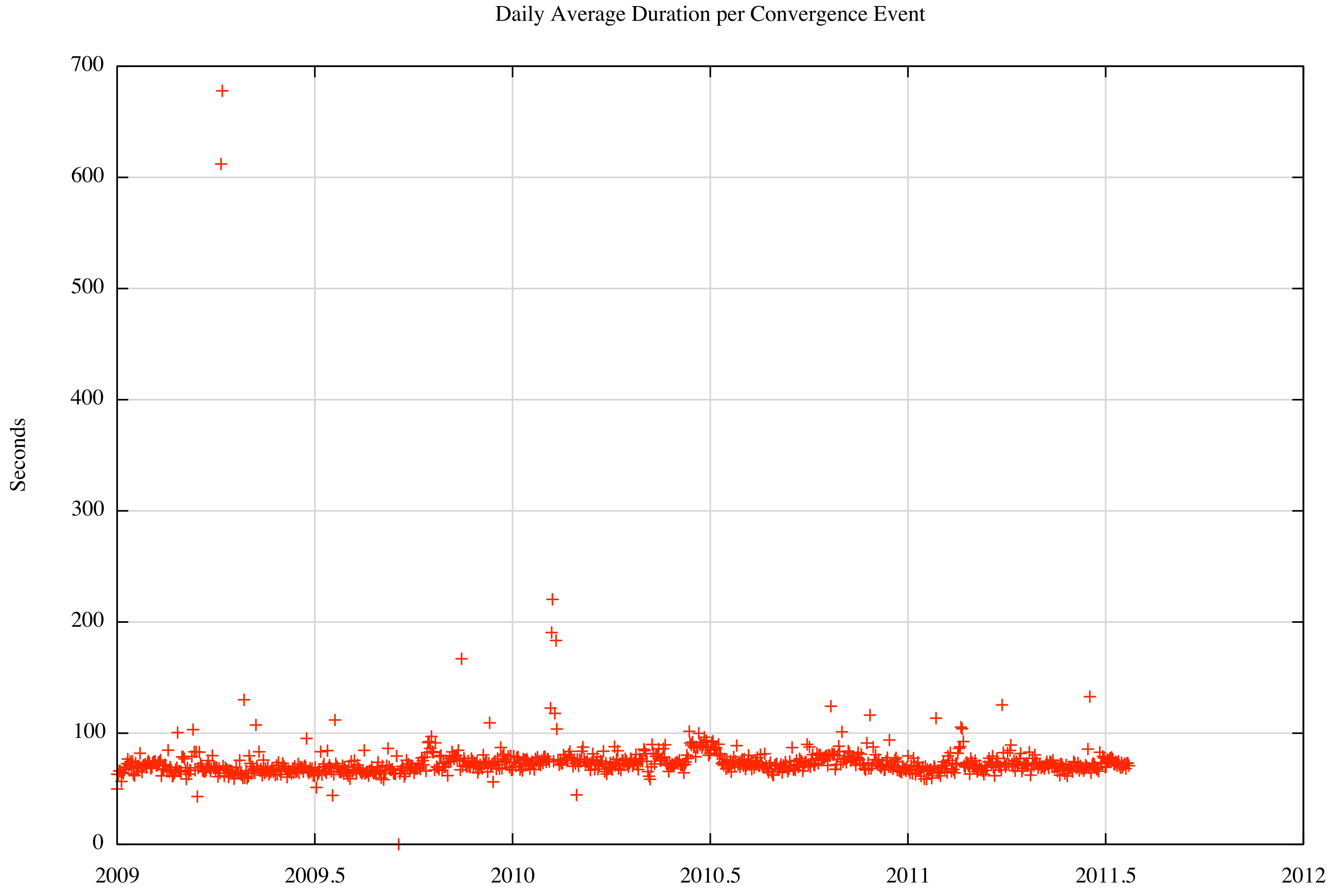
08:02:22 03-Apr + <4777 2516 3549 3327 12976 20483 31323 12654>
08:02:51 03-Apr + <4777 2497 3549 3327 12976 20483 39792 8359 12654>
08:03:52 03-Apr + <4777 2516 3549 3327 12976 20483 39792 6939 16150 8359 12654>
08:04:28 03-Apr + <4777 2516 1239 3549 3327 12976 20483 39792 6939 16150 8359 12654>
08:04:52 03-Apr - <4777 2516 1239 3549 3327 12976 20483 39792 6939 16150 8359 12654>

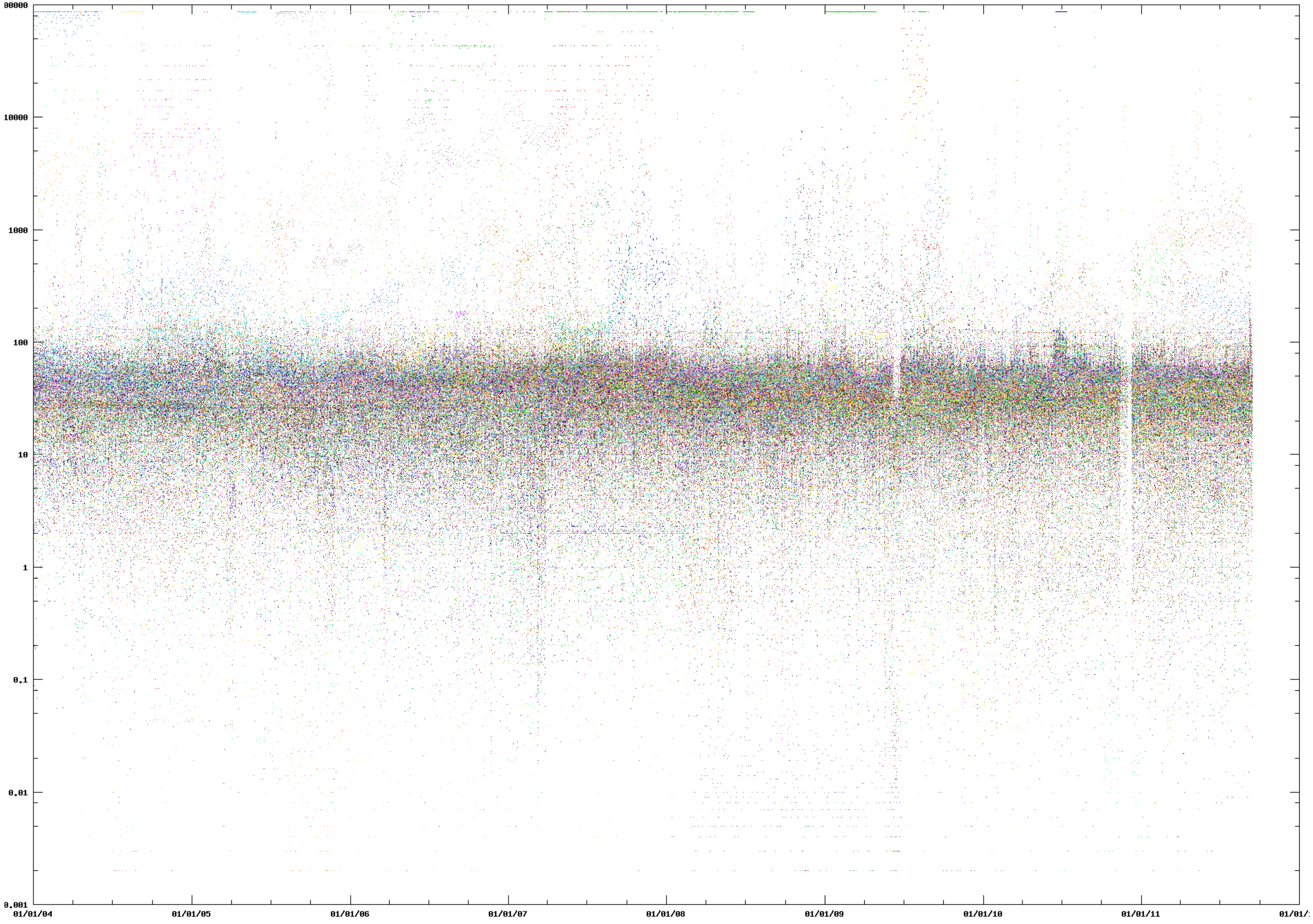
1 withdrawal at source generated a convergence sequence of 5 events, spanning 150 seconds

Convergence – Updates per Event

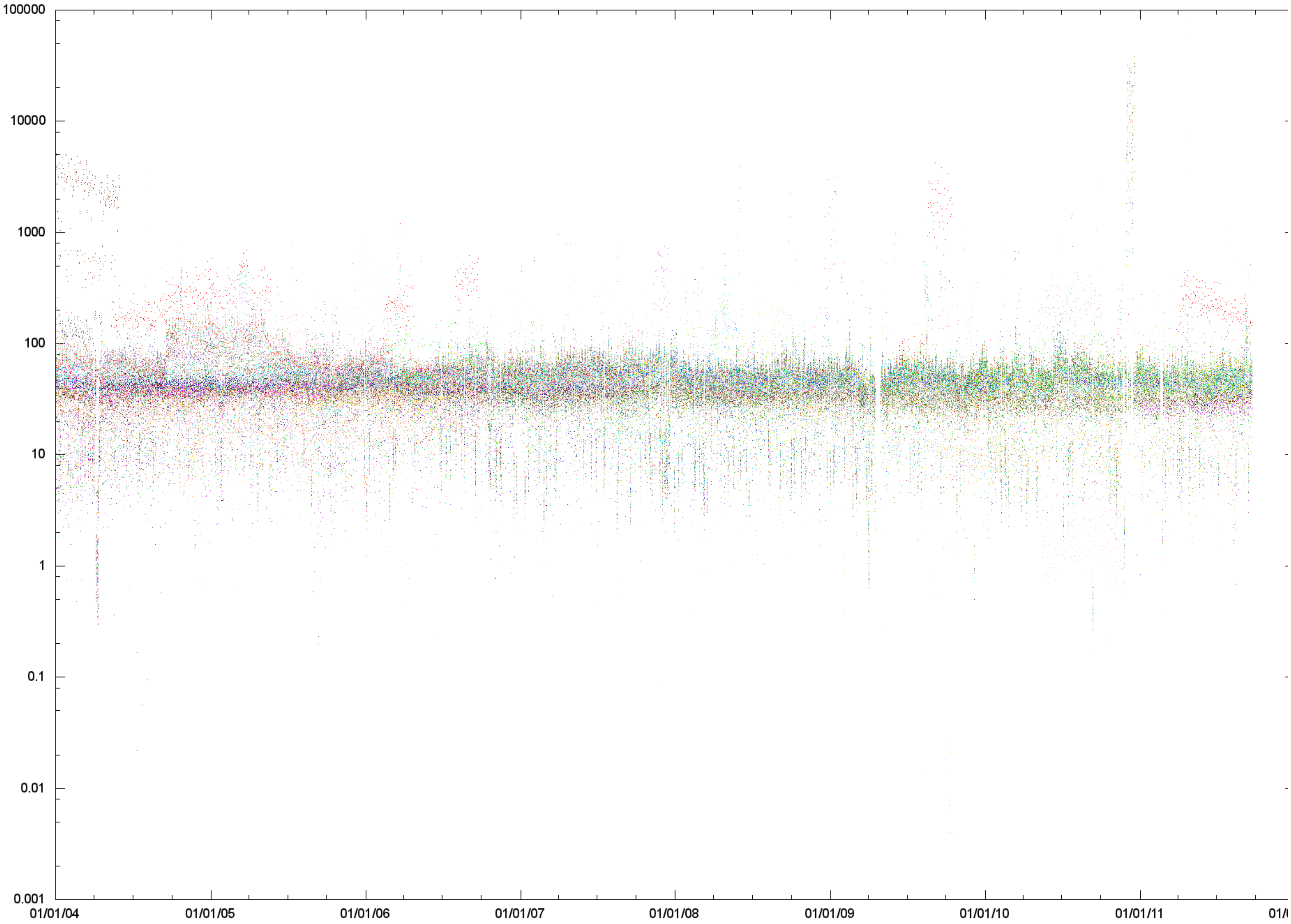


Convergence – Time per Event





Average Convergence Time for RIS peers – 2004 to 2011



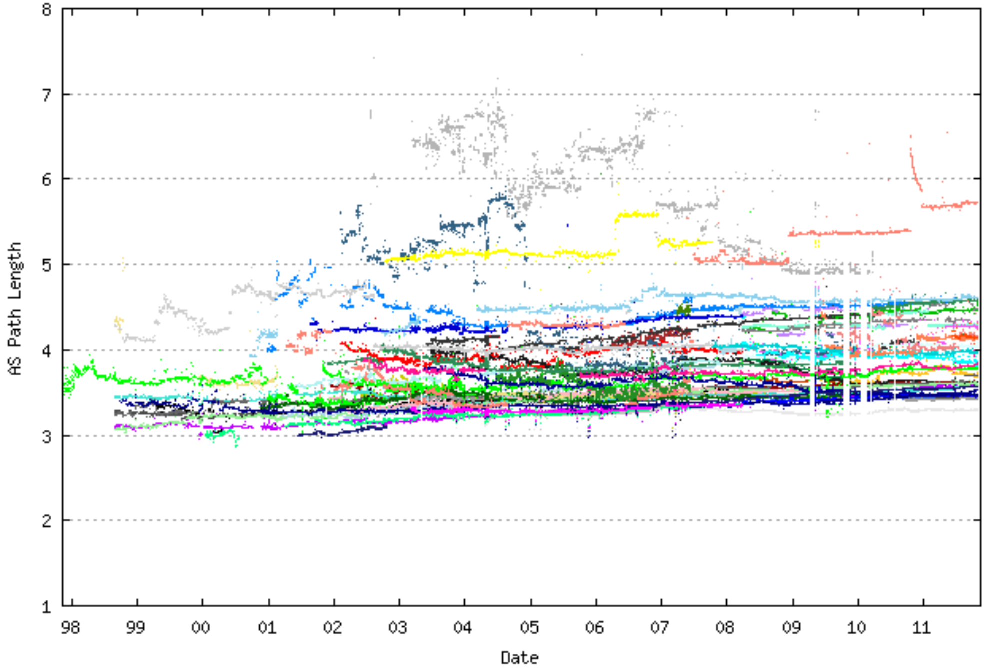
Average Convergence Time for Route Views peers – 2004 to 2011

Convergence Behaviour

- BGP convergence times and average convergence update counts have been constant for the past 7 years
- This implies that a critical aspect of the network's topology has also been held constant over the same period

AS Path is Constant

- The AS Path Length has been constant for many years, implying that the convergence effort has also remained constant

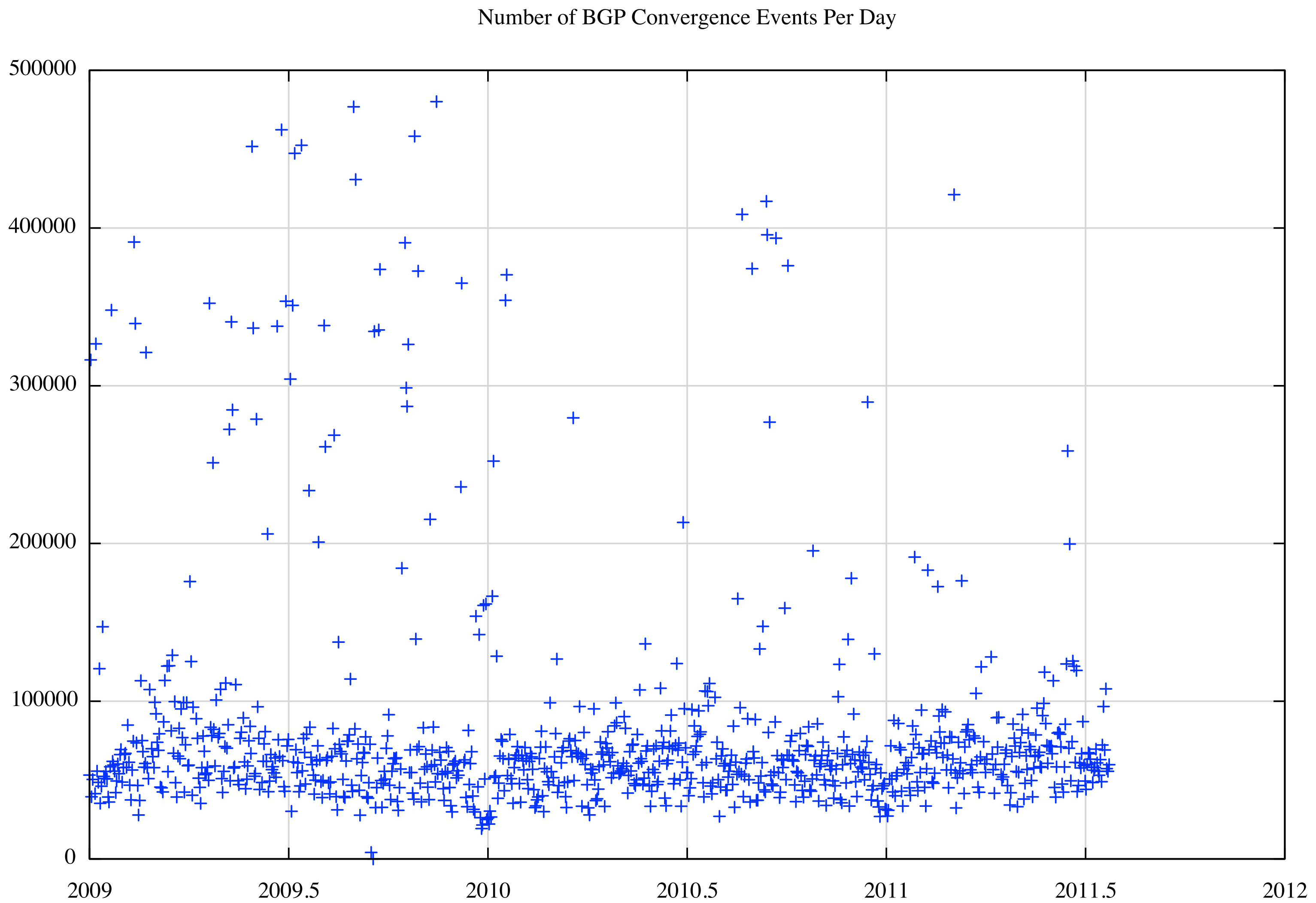


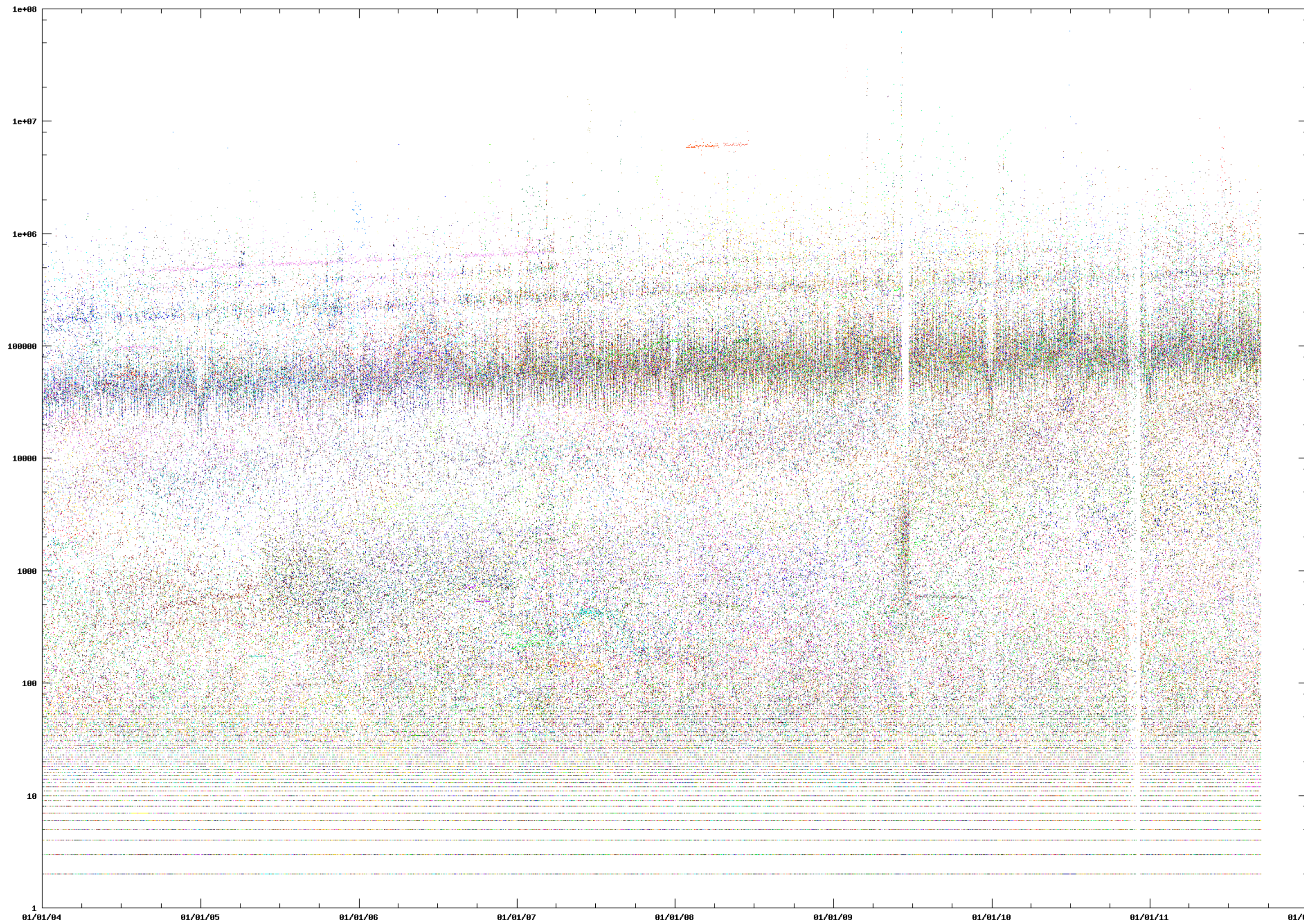
Per-peer average
AS Path Length as
Measured by Route-Views
Peers, 1998 - 2011

BGP Updates

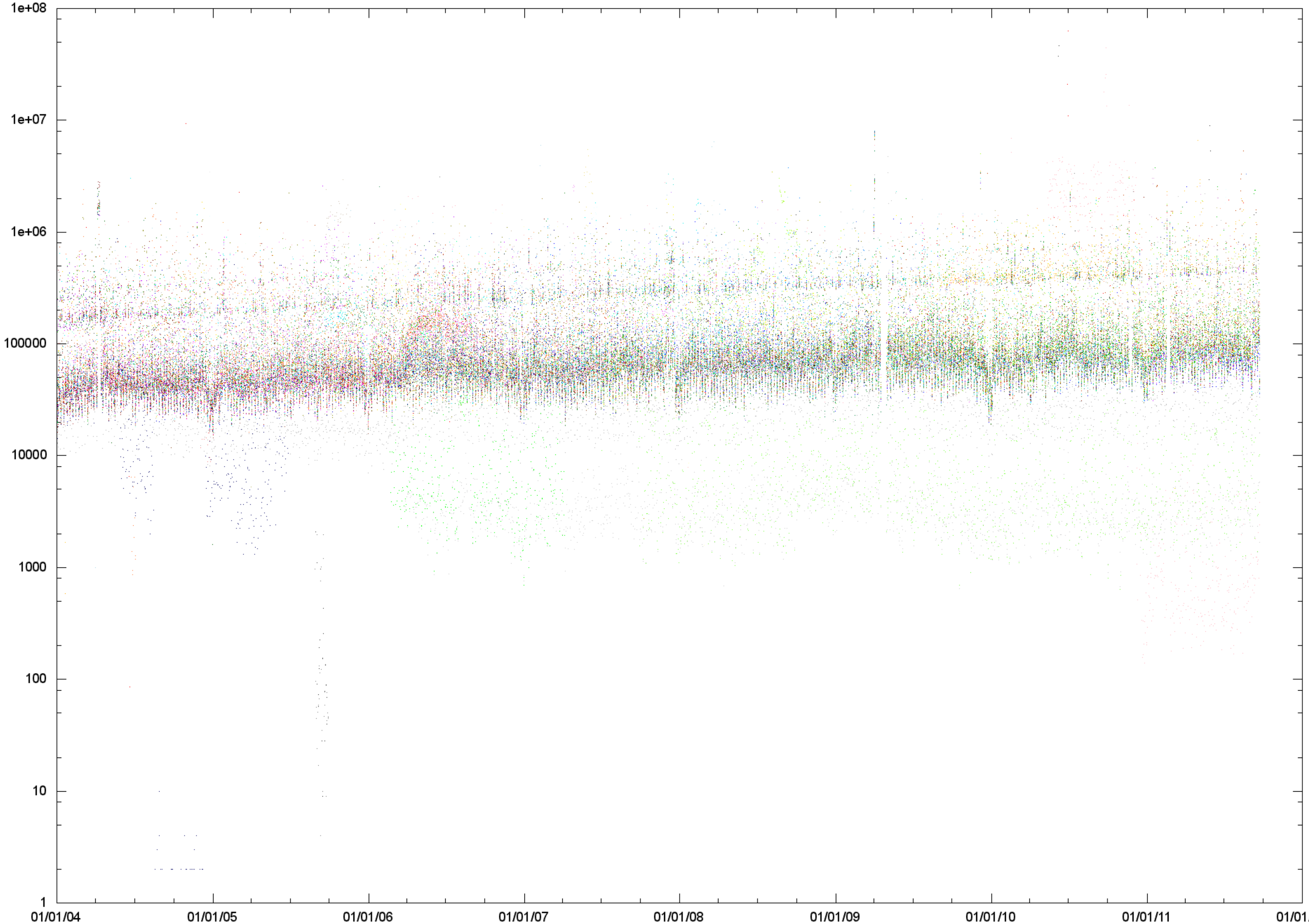
- There are two components to BGP update activity:
  1. Convergence updates as BGP searches for a new stable "solution"
     - AS Path lengths have been steady as the Internet grows by increasing the density of interconnection, not by increasing average AS Path length
  2. The update relating to the "primary" event

BGP "Convergence Events" Per Day





Daily Convergence Event Count for RIS peers – 2004 to 2011

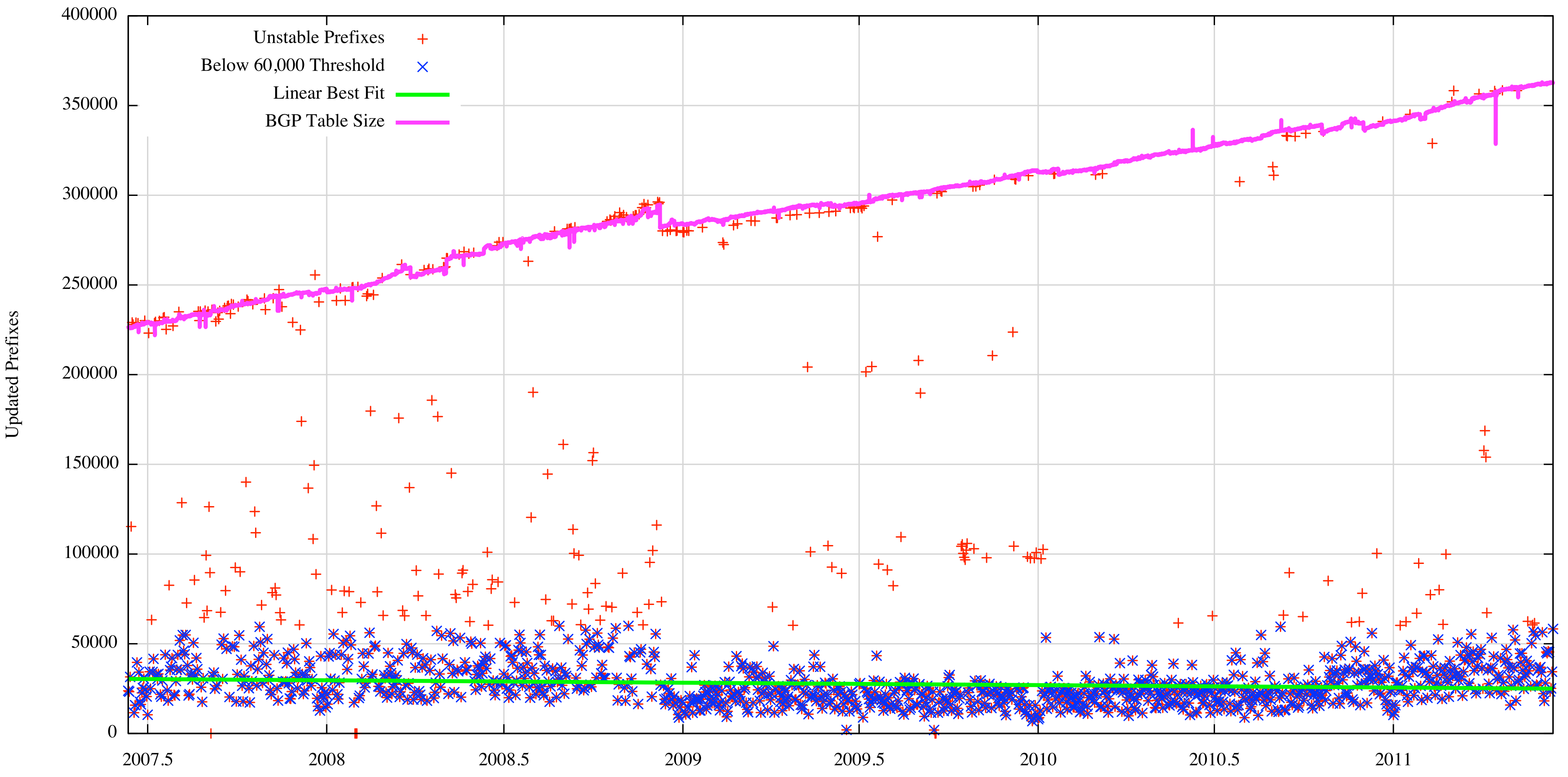


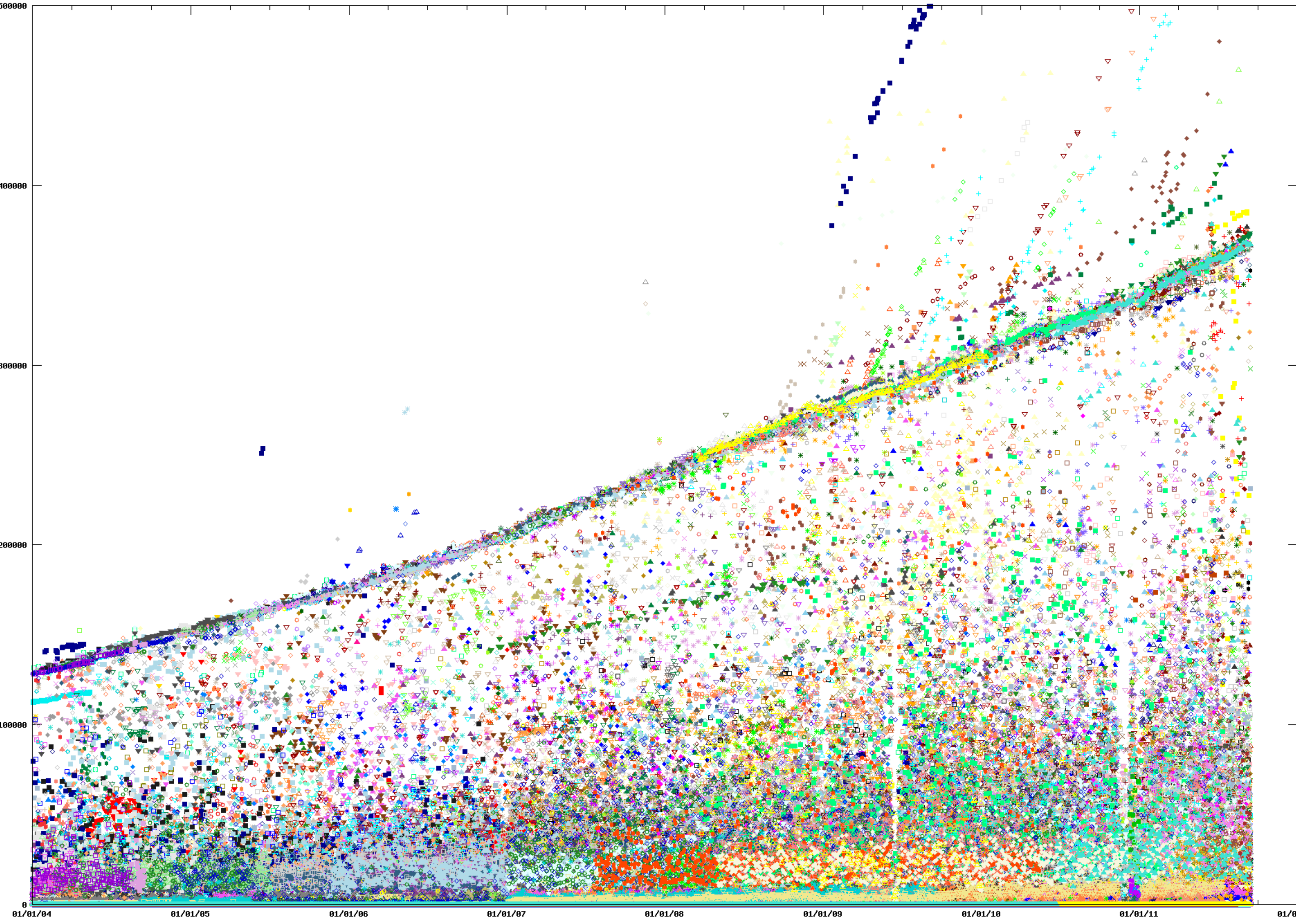
Daily Convergence Event Count for Route Views peers – 2004 to 2011

Unstable Prefixes

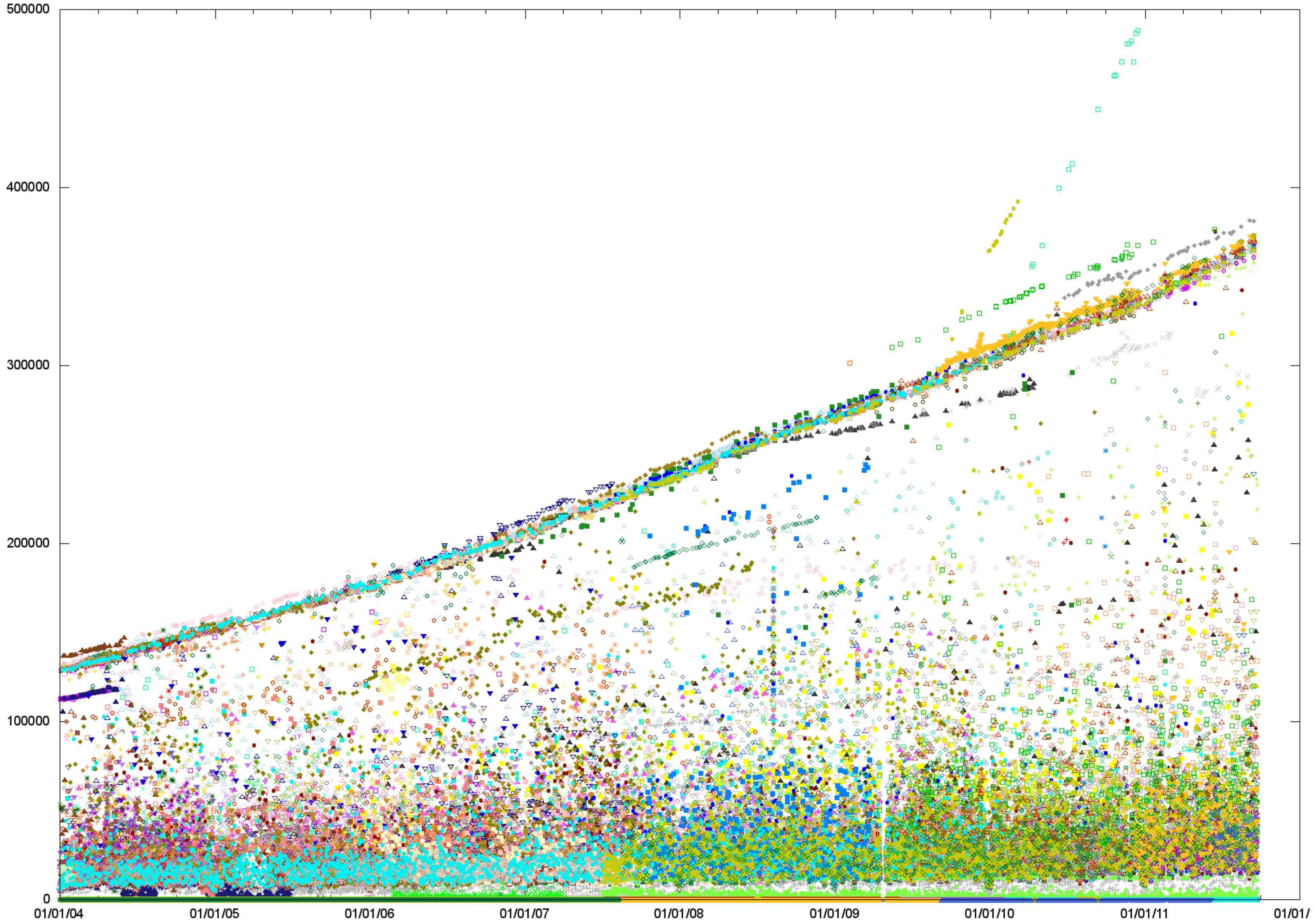
- Are we seeing the same prefixes exhibiting instability multiple times per day, or different prefixes?
- What's the profile of instability from the perspective of individual prefixes?

Unstable Prefixes





Unstable Prefixes for RIS peers – 2004 to 2011

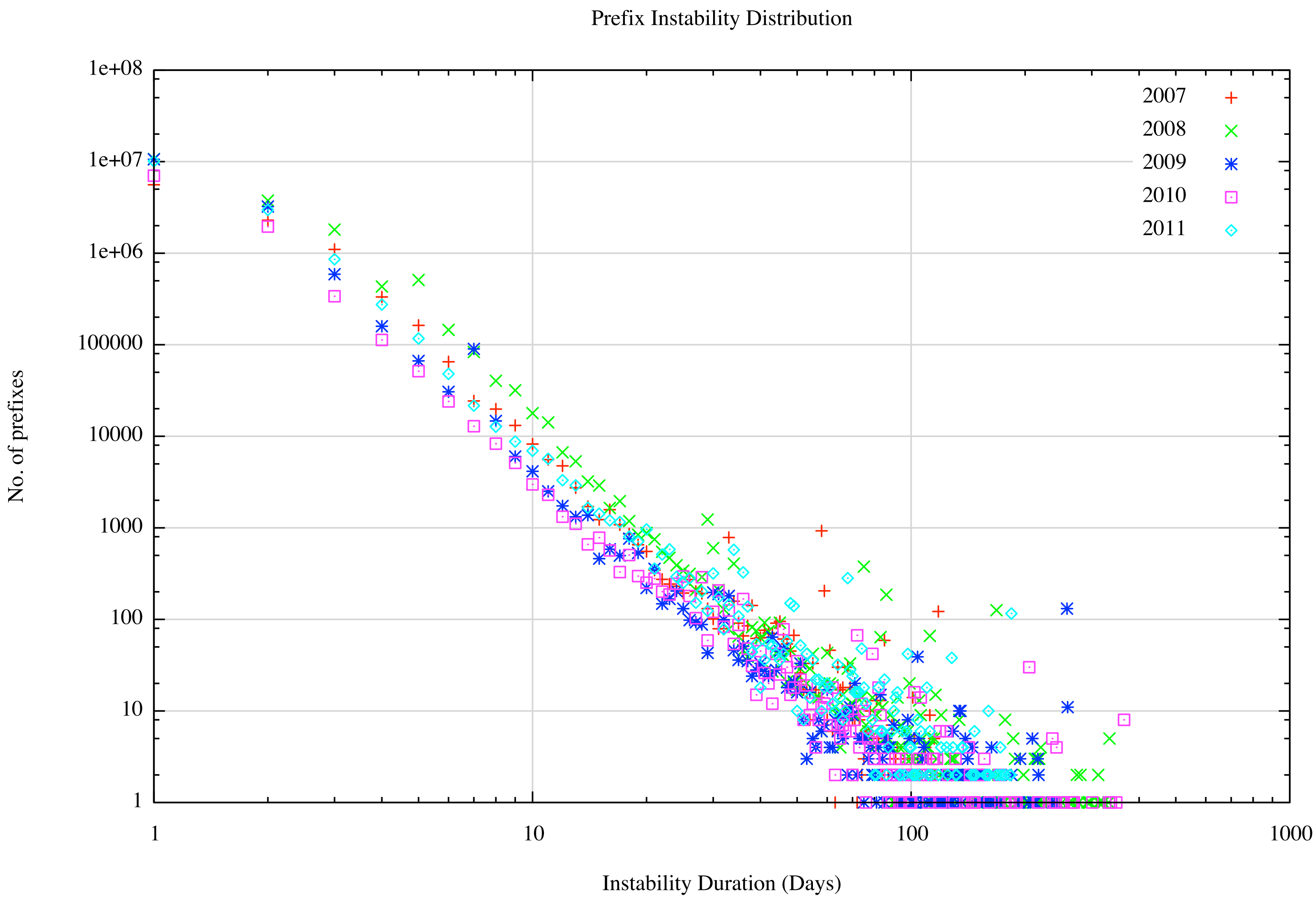


Unstable prefixes for Route Views peers – 2004 to 2011

Unstable Prefixes

- Over the past 4 years the number of unstable prefixes lies between 20,000 – 50,000 prefixes per day
- How “stable” is this set of unstable prefixes?
  - Are they the same prefixes?
  - Are they equally noisy?
  - What are the characteristics of this “noise”?

Prefix Instability Duration



Prefix Instability

- Prefix Instability is generally short lived
  - 90% of all prefixes are unstable for 2 days or less
  - 6 prefixes are persistently unstable – these are beacon prefixes.
- The distribution of the duration of prefix instability at a coarse level (per day) appears to be a power law distribution (see Zipfs'Law)

Flat Worlds

- The average number of convergence events appears to be basically flat for the past couple of years
  - The growth rate appears to be far lower than the growth rate of the routing table itself
- The number of unstable prefixes per day is also relatively long term constant
  - but the individual prefixes themselves are unstable for 1 – 2 days on average

Why is BGP Flat?

- The convergence amplification factor is governed by the bounded diameter of the Internet
- But why hasn't the number of unstable prefixes grown in line with the growth in the table size? What is limiting this behaviour of the routing system? Why 20-50K unstable prefixes per day? Why not 100K? Or 5K? What is bounding this observed behaviour?

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Thank You

Questions?