Measuring BGP

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BGP is …

- An instance of the Bellman-Ford Distance Vector family of routing protocols
  - And a relatively vanilla one at that
- The routing protocol used to support inter-domain routing in the Internet
  - So its pretty important!
- A means of inferring the structure of interconnections within the Internet
  - Which means both its behaviour as a protocol and the content of the protocol messages are extremely interesting artifacts!

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BGP metrics can provide:

- Information on the internal structure and growth of the Internet
- Scaling properties of the routing base
- Consumption rates of IP address resources
- Capabilities to provide enhanced security within the routing system

Measuring BGP

- 3 primary data acquisition mechanisms:
  - Sequence of hourly dumps of the BGP RIB
    - "show ip bgp"
      - Shows prefixes, paths, and attributes at that time held by the target router
  - Update Log of BGP speaker
    - "log updates"
      - Shows timestamp and BGP Update packet log of every BGP message in all peer sessions
  - Controlled Experimentation
    - Controlled announcement and withdrawal of a prefix
      - Shows the nature of protocol-based amplification of a known "root cause" event

Measuring BGP

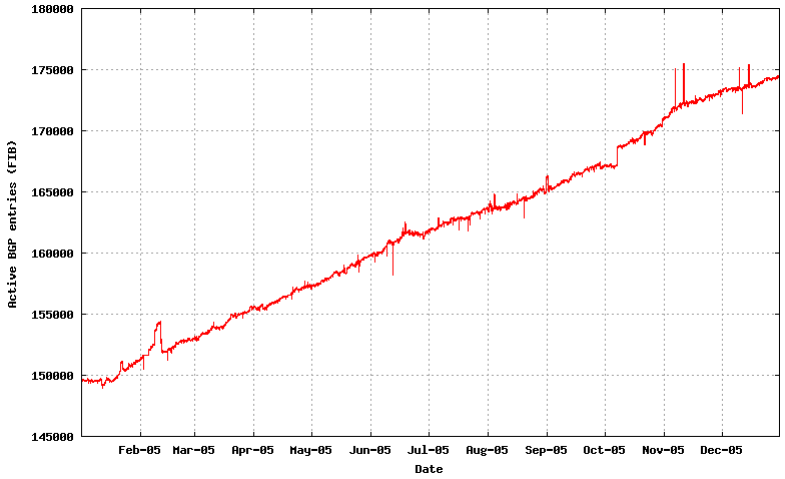
- Periodic snapshots
  - No high frequency (protocol convergence) information
  - Heavily filtered by the collector's perspective (no uniform visibility of localised connections)
  - Useful for some forms of trend analysis
- Update Analysis
  - Very high component of protocol convergence data
  - Highly influenced by collector's perspective
  - Can be useful to distinguishing between network and protocol components
- Controlled Experimentation
  - Major value in determination of underlying network cause vs protocol instability
  - Difficulty in replication of experimental outcomes

Objectives of this Work

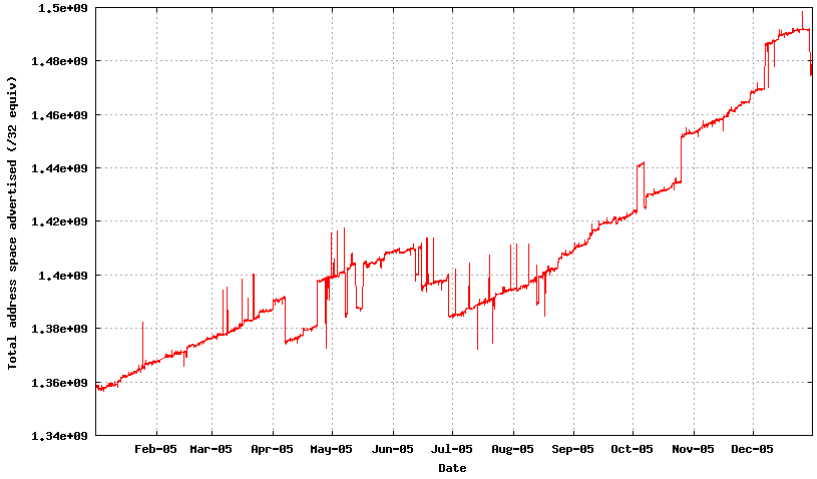
Look at the "whole" of the Internet for 2005 and attempt to understand the network's characteristics in terms of "whole of network" metrics

Look at the behaviour of the Internet's inter-domain routing system and attempt to understand the correlation of projections of router capacity and routing protocol load

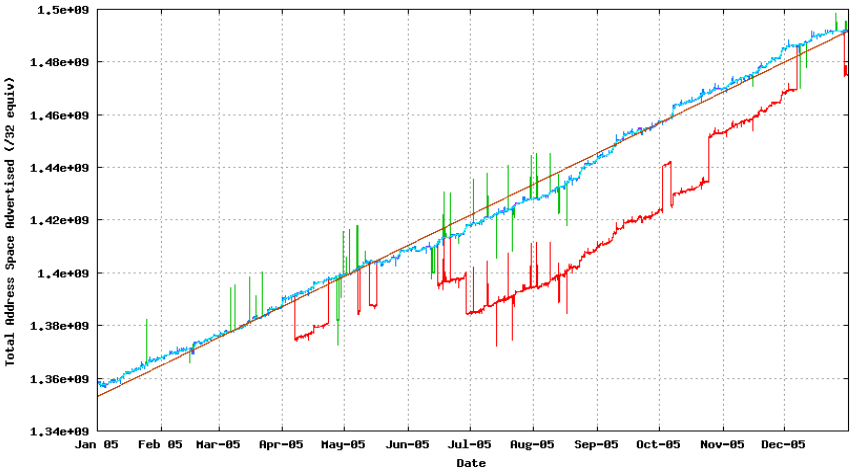
IPv4 in 2005
Total Advertised BGP Prefixes



IPv4 in 2005
Total Advertised Address Span

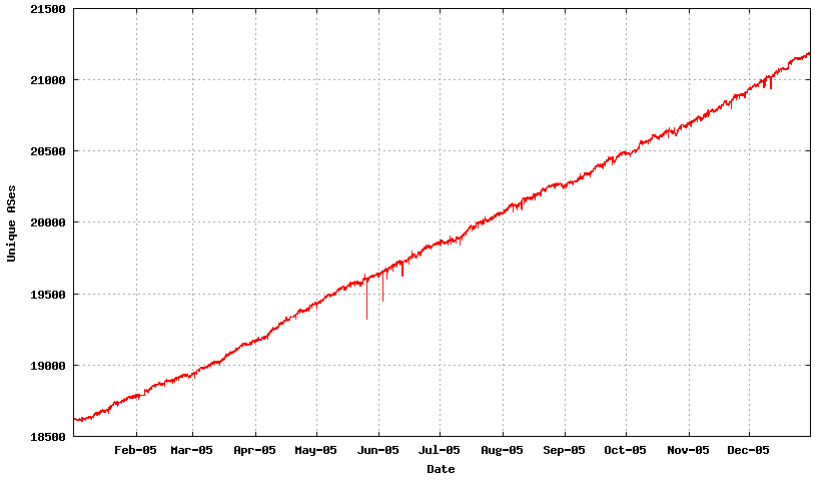


IPv4 in 2005
Total Advertised Address Span



http://ipv4.potaroo.net

IPv4 in 2005
Total Advertised AS Numbers



IPv4 – Vital Statistics for 2005

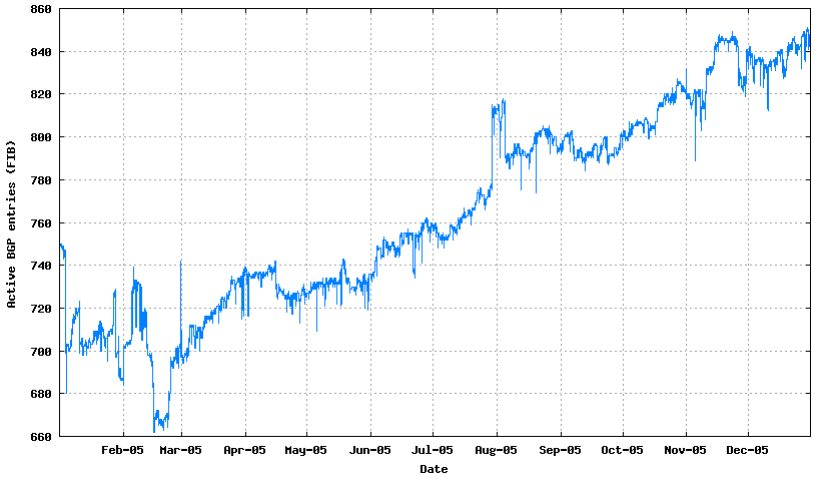
Prefixes	148,500 – 175,400	+18%	26,900
Roots	72,600 – 85,500	+18%	12,900
Specifics	77,200 – 88,900	+18%	14,000
Addresses	80.6 – 88.9 (/8)	+10%	8.3 /8s
ASNs	18,600 – 21,300	+14%	2,600

Average advertisement size is getting smaller
Average address origination per AS is getting smaller
Average AS Path length steady at 3.5
AS interconnection degree up

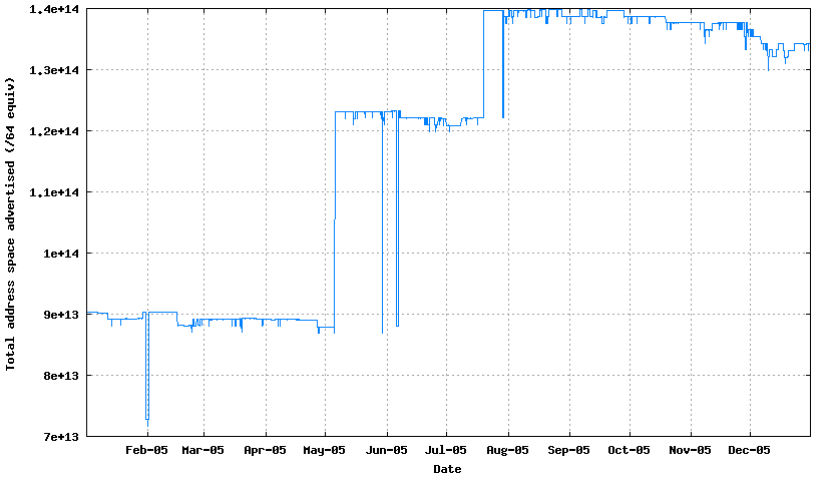
The IPv4 network continues to get denser, with finer levels of advertisement granularity.

More interconnections, more specific advertisements

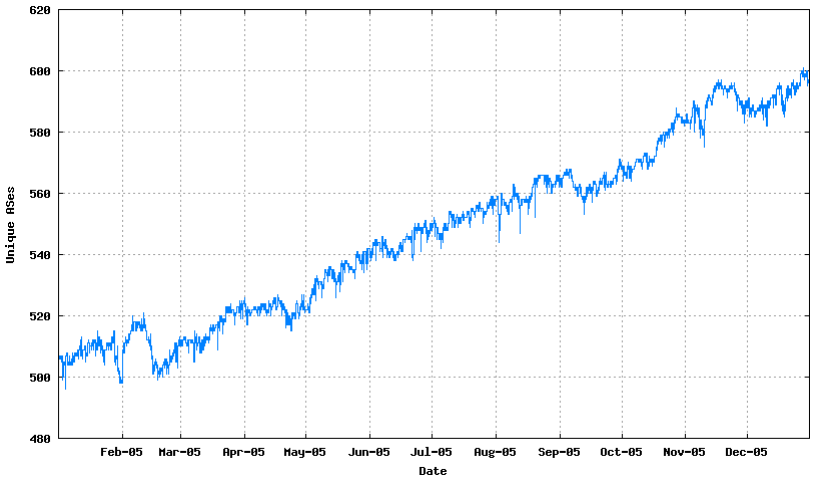
IPv6 in 2005
Advertised Prefix Count



IPv6 in 2005
Advertised Address Span



IPv6 in 2005
Total Advertised AS Numbers



IPv6 – Vital Statistics for 2005

Prefixes	700 – 850	+21%
Roots	555 – 640	+15%
Specifics	145 - 210	+51%
Addresses	9 – 13.5 (10**13)	+50%
ASNs	500 – 600	+20%

Average advertisement size is getting larger
Average address origination per AS is getting larger
Average AS Path length variable between 3 – 5
AS interconnection degree variable

Through 2005 the IPv6 network remained small and continued to use a very large proportion of overlay tunnels at the edges. Larger scale trends in network characteristics were not readily discernable from 2005 figures

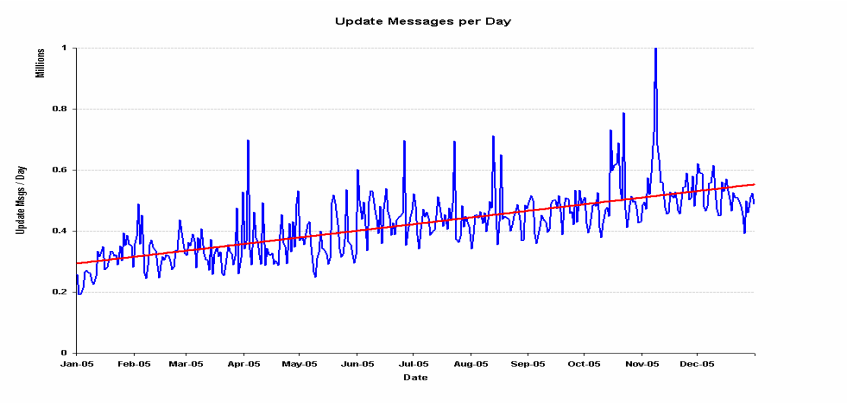
The Scaling Question:

If you were buying a large router suitable for use in a "DFZ" with an expected lifetime of 3-5 years, what would you specify as the number of IPv4/IPv6 prefixes it must be able to handle? And how many prefix updates per second?

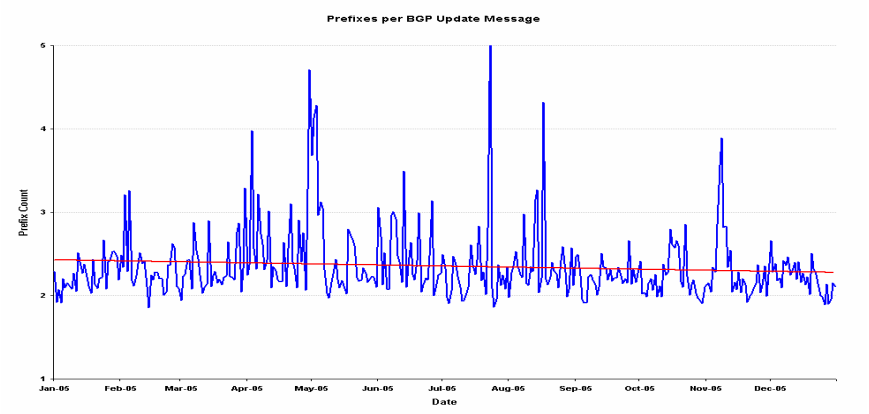
BGP Update Study - Methodology

- Examine update and withdrawal rates from BGP log records for 2005 from a viewpoint within AS1221
  - Eliminate local effects to filter out non-DFZ BGP updates
  - Look at the relative rate of updates and withdrawals against the table size
- Generate a BGP table size predictive model and use this to generate 3 – 5 year BGP size and update rate predictions

Update Message Rate



Prefixes per Update Message



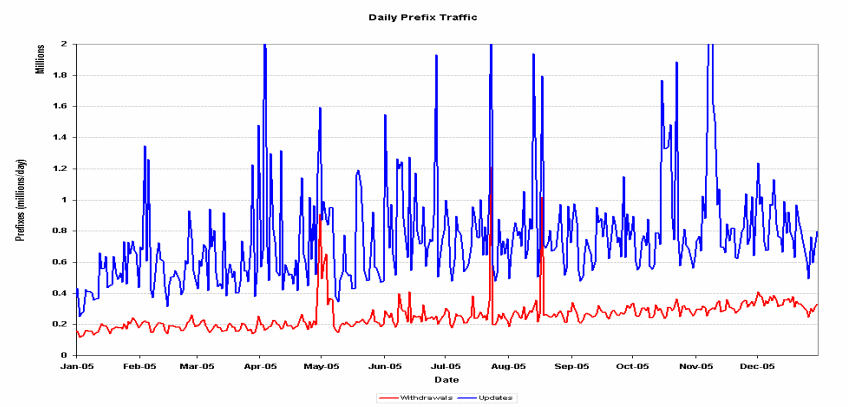
Update Trends across 2005

- Number of update messages per day has doubled across 2005 (Dec 2005 saw approx 550,000 update messages per day)
  - Considering the large population, the daily update rate is highly variable – why?
- Number of prefixes per update message is falling from an average of 2.4 to 2.3 prefixes per update
  - Is this attributable to increased use of public ASs and eBGP at the edge of the network? (Multi-homing?)
- Is the prefix update rate increasing at a greater rate than the number of prefixes in the routing table?
  - Is there some multiplicative factor at play here?
  - Why is instability increasing faster than the network size?

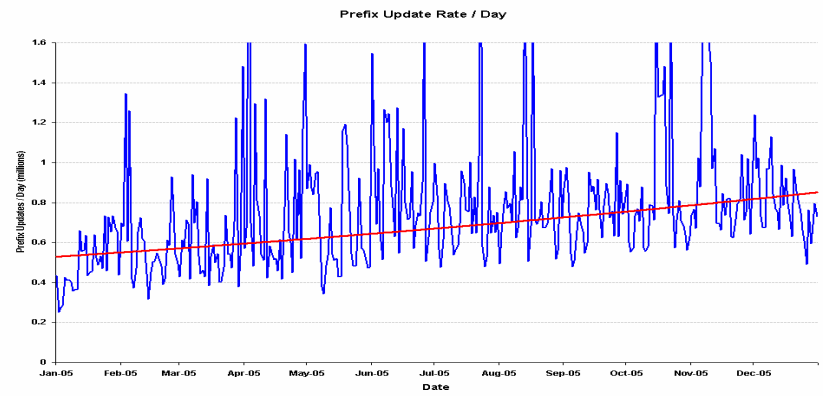
Prefixes vs Updates

- Look at the number of prefixes that are the subject of update messages
- What are the trends of prefix update behaviour?

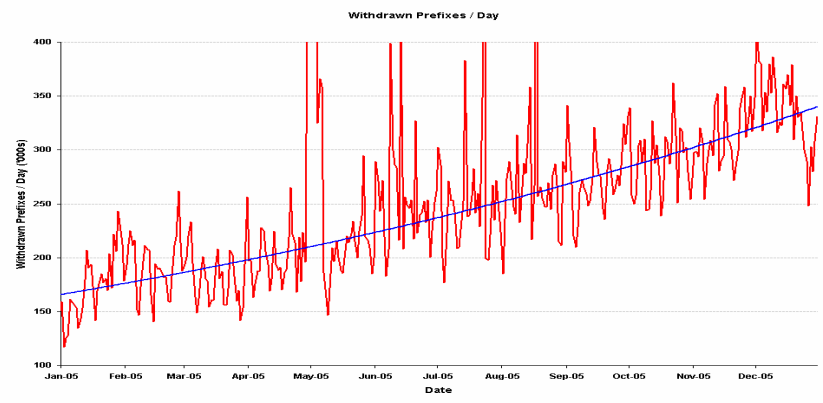
Prefix Update and Withdrawal Rates



Prefix Update Rates



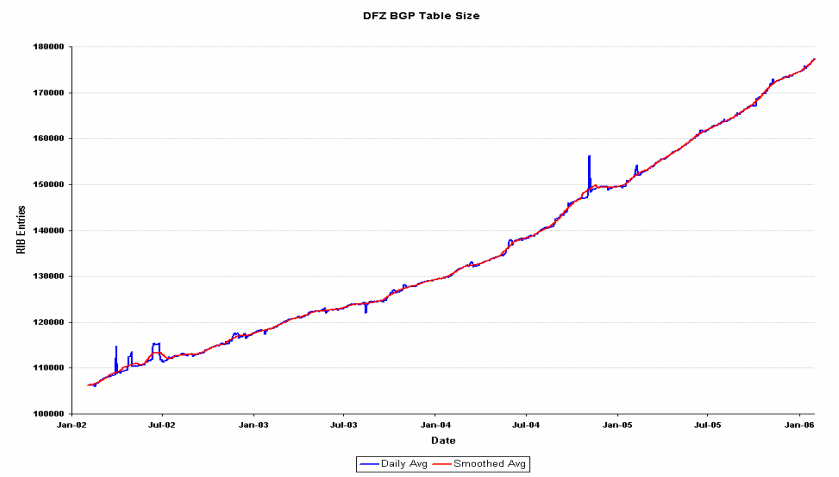
Withdrawal Rates



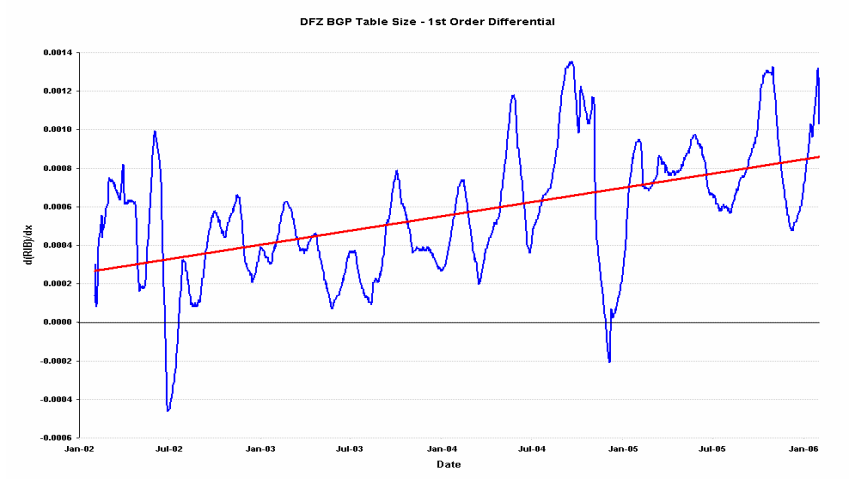
Prefix Rate Trends

- High variability in day-to-day prefix change rates
- Best fit model appears to be exponential – although update and withdrawal rates show different growth rates

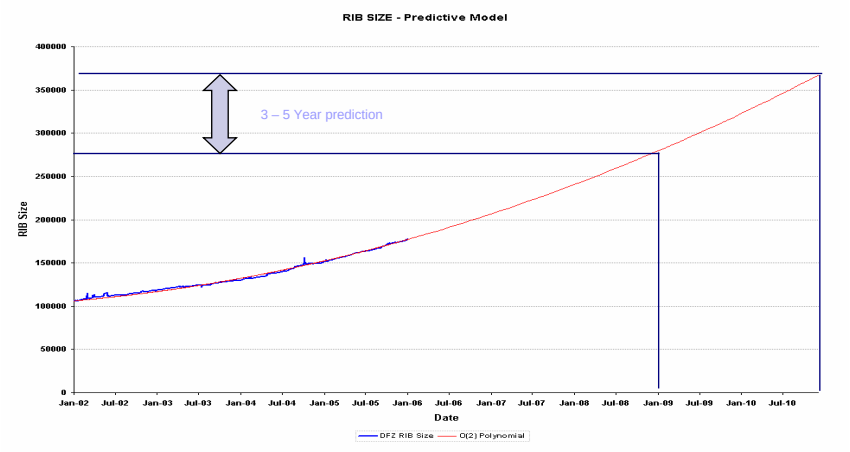
BGP Prefix Table Size



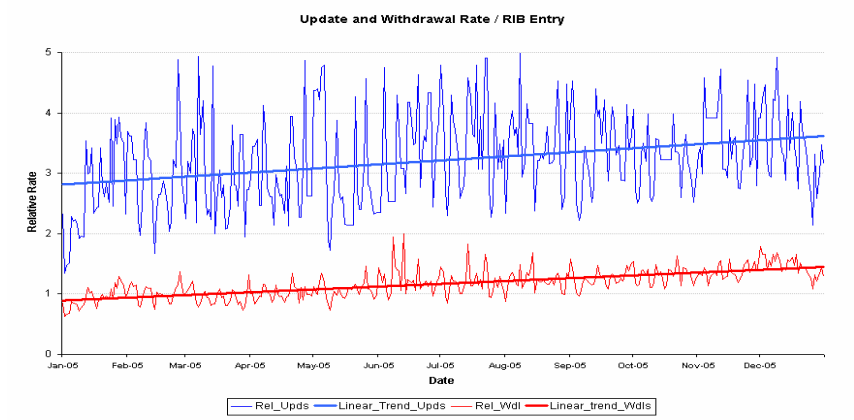
1st Order Differential



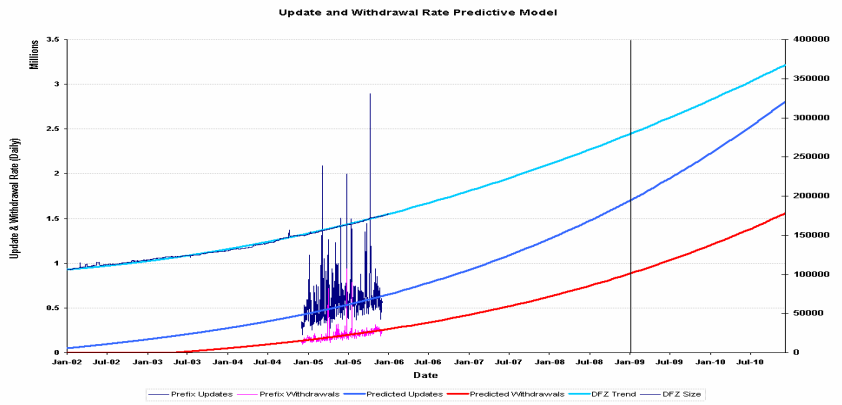
DFZ Model as an O(2) Polynomial



Relative Update / Withdrawal Rates



Update Rate Prediction



3-5 Year Predictions for IPv4 Default Free Zone

- Today (1/1/2006)
  - Table Size **176,000** prefixes
  - Update Rate 0.7M prefix updates / day
  - Withdrawal Rate 0.4M prefix withdrawals per day
- 3 Years (1/1/2009)
  - Table Size **275,000** prefixes
  - Update Rate 1.7M prefix updates / day
  - Withdrawal Rate 0.9M withdrawals per day
- 5 Years (1/1/2011)
  - Table Size **370,000** prefixes
  - Update Rate 2.8M prefix updates / day
  - Withdrawal Rate 1.6M withdrawals per day

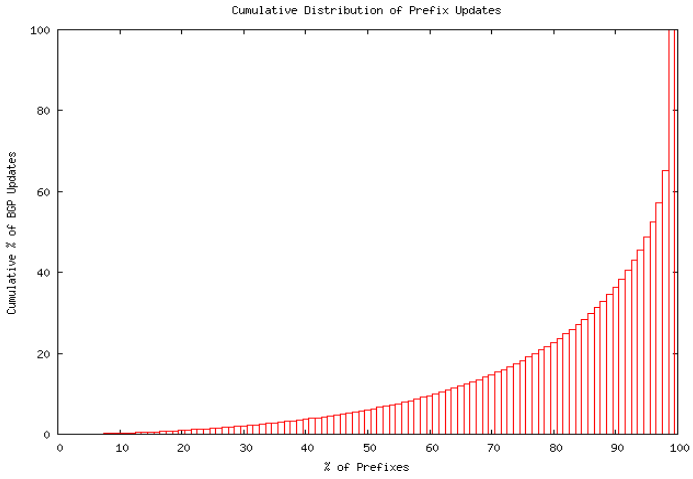
What's the uncertainty factor?

- What is the incremental processing load when we add cryptographic checks into BGP? Does this impact on the projections of BGP update traffic?
- Are these trends reliable? Are we seeing a uniform distribution of updates across all ASs and all Prefixes? Or is this a skewed heavy tail distribution where a small number of prefixes contribute to most of the BGP updates?

Prefix Statistics for 2005

- Number of unique prefixes announced: 289,558
- Prefix Updates: 70,761,786
- Stable prefixes: 12,640
- Updated prefixes (year end): 162,039
- Withdrawn prefixes: 127,519

Cumulative Distribution of Prefix Updates



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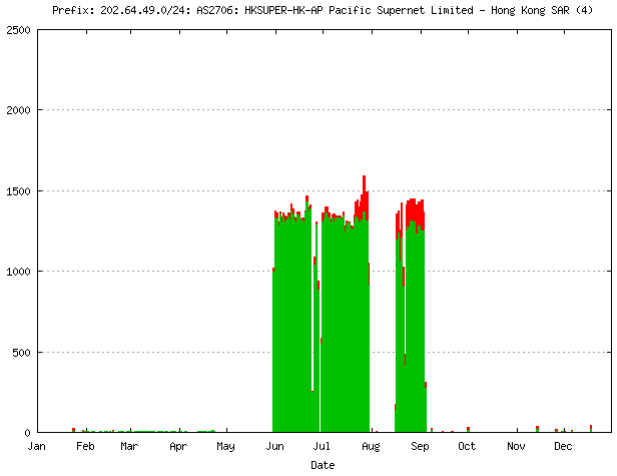
Active Prefixes

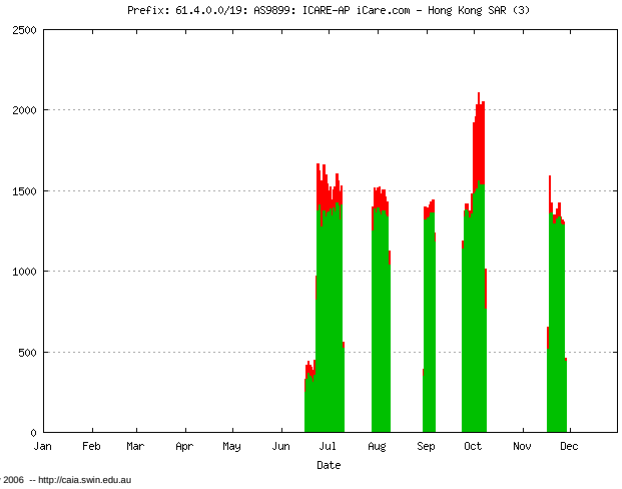
Top 10 Prefixes

	Prefix	Updates	Flaps	AS Re-Homes
1.	202.64.49.0/24	198,370	96,330	918
2.	61.4.0.0/19	177,132	83,277	55
3.	202.64.40.0/24	160,127	78,494	1,321
4.	81.212.149.0/24	158,205	61,455	20,031
5.	81.213.47.0/24	138,526	60,885	12,059
6.	209.140.24.0/24	132,676	42,200	0
7.	207.27.155.0/24	103,709	42,292	0
8.	81.212.197.0/24	99,077	37,441	15,248
9.	66.150.140.0/23	84,956	11,109	5,963
10.	207.168.184.0/24	74,679	34,519	0

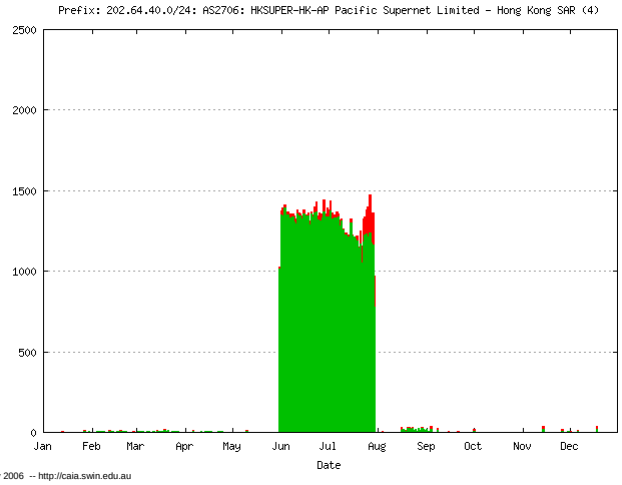
1 - 202.64.49.0/24



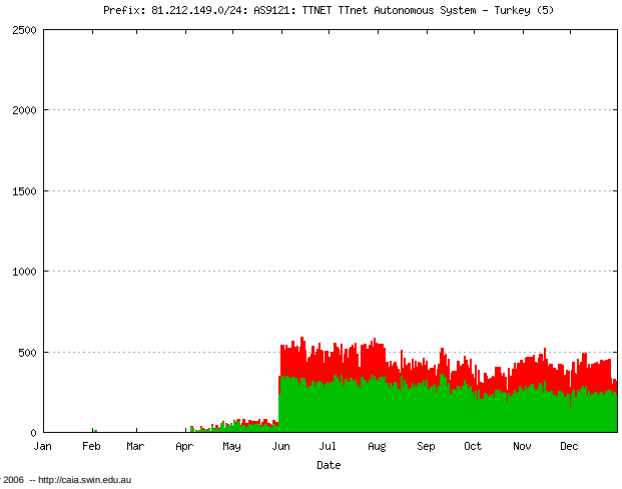
2 - 61.4.0.0/19



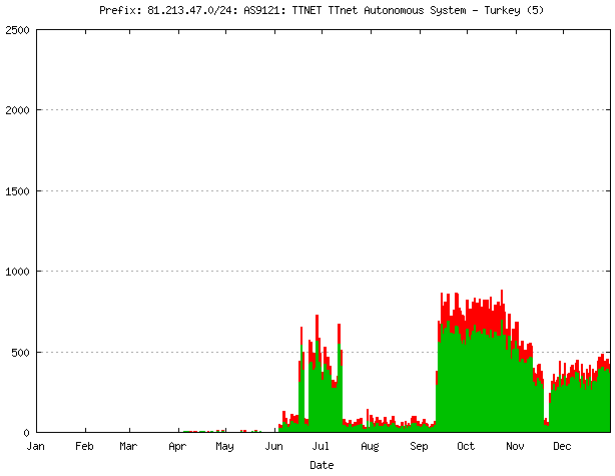
3 - 202.64.40.0/24



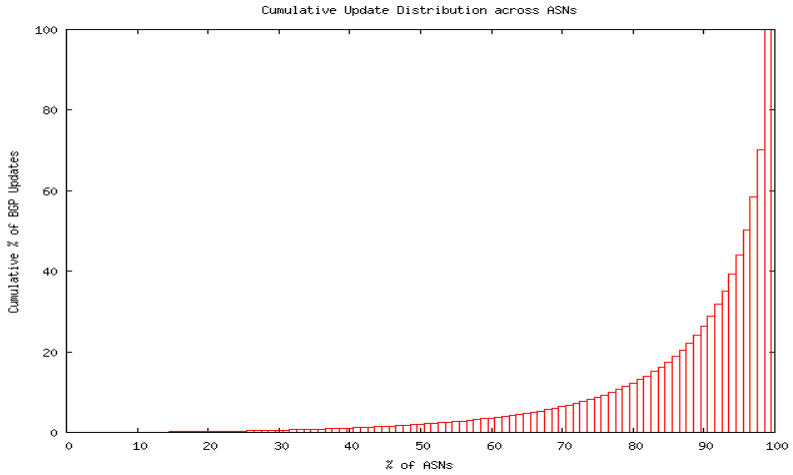
4 - 81.212.149.0/24



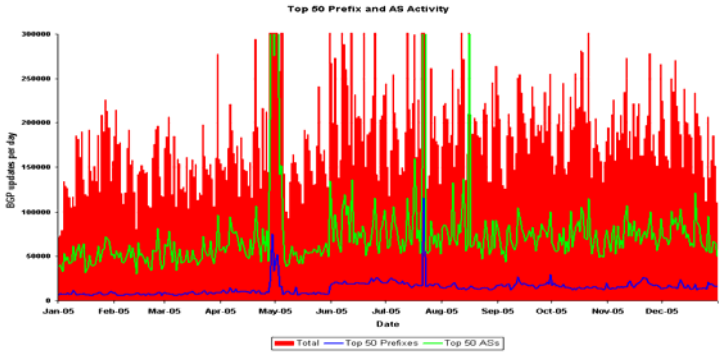
5 - 81.213.47.0/24



Distribution of Updates by Origin AS



Distribution of Updates

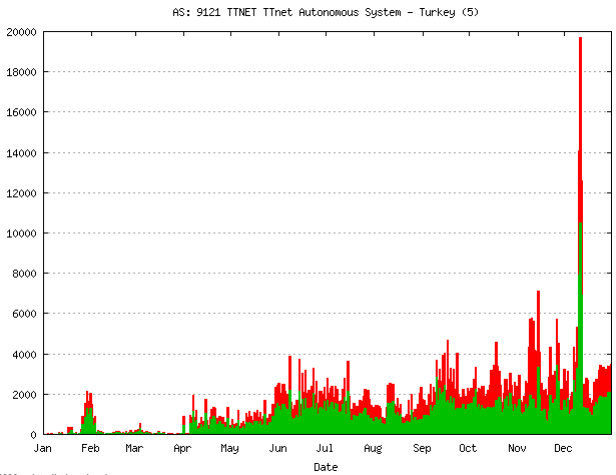


Active ASNs

Top 10 ASns

	AS	Updates	Flaps	AS Re-Homes
1.	9121	970,782	349,241	206802
2.	7563	869,665	326,707	5
3.	702	605,090	232,876	144523
4.	17557	576,974	178,044	175275
5.	17974	569,806	198,948	310
6.	7545	562,879	200,425	8931
7.	721	498,297	175,623	35866
8.	2706	418,542	196,136	16945
9.	9950	411,617	148,725	6
10.	17832	393,052	143,018	0

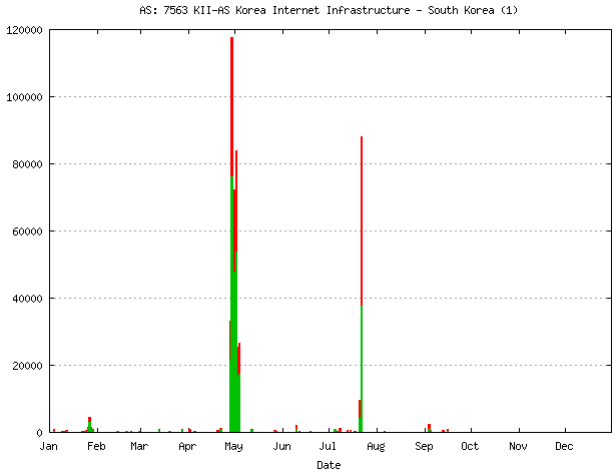
1 – AS 9121



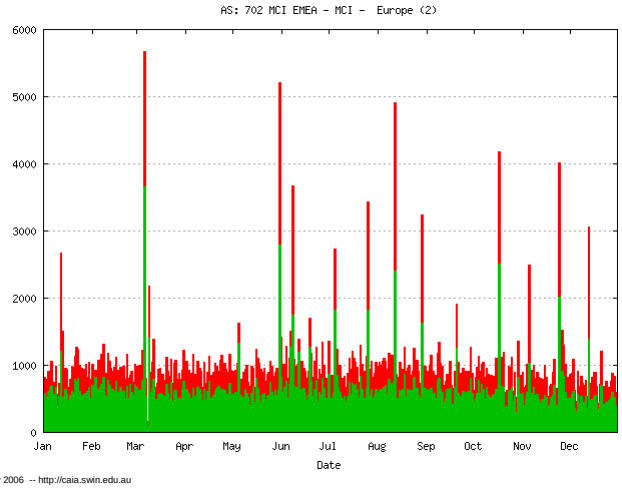
AS9121 Upstreams

- 9121 TTNET TTnet Autonomous System Adjacency: 84 Upstream: 6 Downstream: 78
- Upstream Adjacent AS list
  - AS1299 TELIANET TeliaNet Global Network
  - AS3257 TISCALI-BACKBONE Tiscali Intl Network
  - AS3356 LEVEL3 Level 3 Communications
  - AS3549 GBLX Global Crossing Ltd.
  - AS13263 METEKSAN-NET Meteksan.NET Autonomous System
  - AS6762 SEABONE-NET Telecom Italia Sparkle

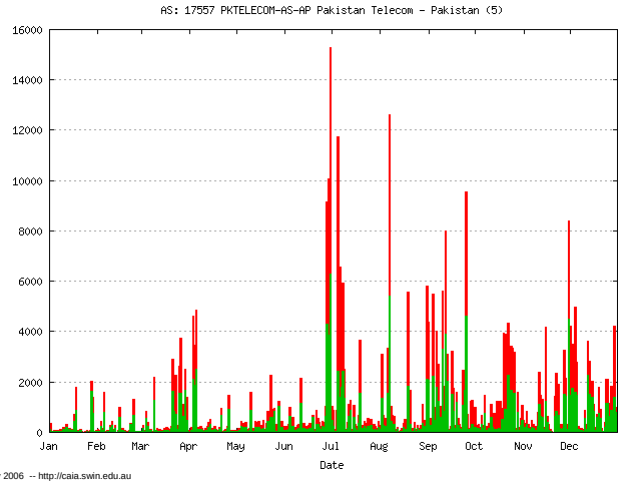
2 – AS 7563



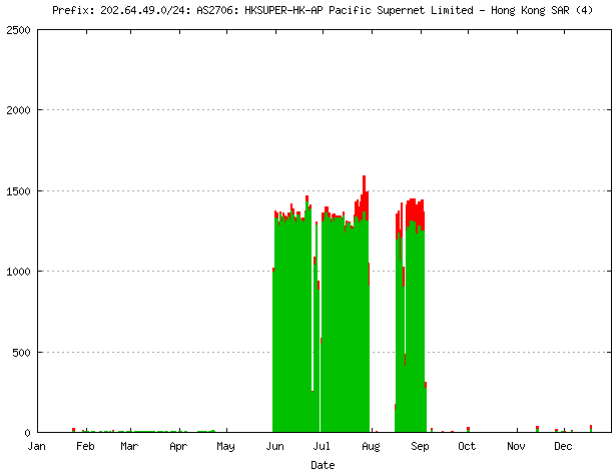
3 – AS 702



4 – AS 17557



5 – AS17974



So what's going on?

- It would appear that the BGP update rate is being strongly biased by a small number of origins with two forms of behaviour:
  - **Traffic Engineering** - consistent update rates sustained over weeks / months with a strong component of first hop change and persistent announce and withdrawal of more specifics
  - **Unstable configuration states** – a configuration which cannot stabilise and for a period of hours or days the update rate is extremely intense

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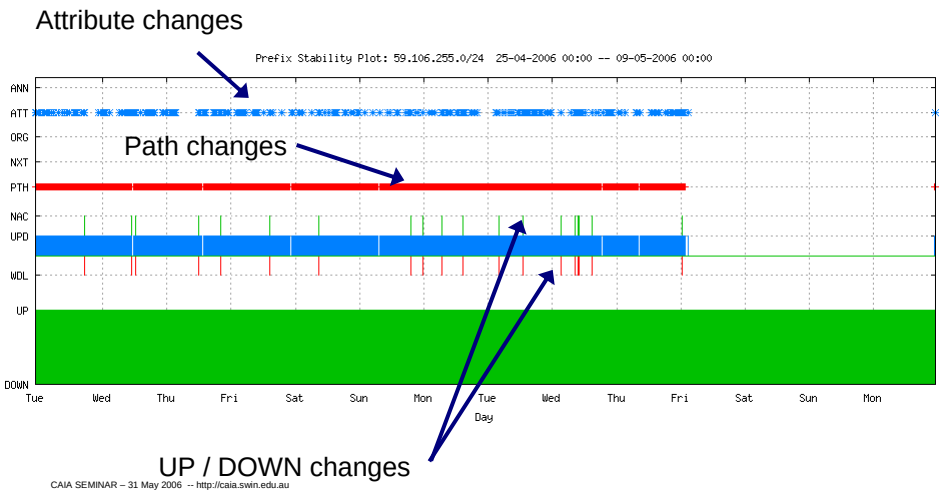
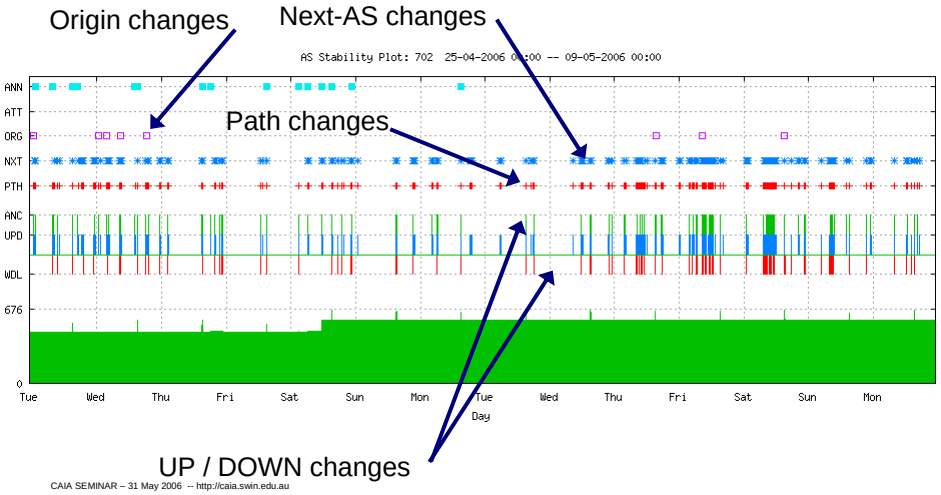
The Uncertainty Factor

- Given that the overwhelming majority of updates are being generated by a very small number of sources, the level of uncertainty in extrapolation of trend models of BGP update rates is extremely high
- This implies that the predictions of router capabilities in a 3 – 5 year interval is also extremely uncertain

Per-Prefix 14 Day Display



Per-AS 14 Day Display



Next Steps…

- Can we identify and report on persistent BGP update generators?
  - Yes
- Generate per-Prefix and per-AS views and update stats summaries in an on-demand rolling 14 day window
  - done – see http://bgpupdates.potaroo.net
- Correlation of path updates
  - Work-in-progress
- Can the noise component be filtered out of the protocol updates? What is the rate of actual information change in routing vs the protocol-induced amplification of the information update?
  - Work-in-progress