DNS Caching: Running on Zero

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Domain Name Service

- Distributed name resolution service
- Maps Fully Qualified Domain Names (FQDNs) to DNS records:
  e.g. FQDN (www.cs.st-andrews.ac.uk) to a DNS A record (IPv4 Address, 138.251.206.45),
- Also provides other administrative data for specific services (a simple directory service):
  - Name Servers for a domain (NS records)
  - Mail servers (MX records)
  - Jabber (and other) servers (SRV records)
  - Other record types are possible …

Motivation for examining DNS

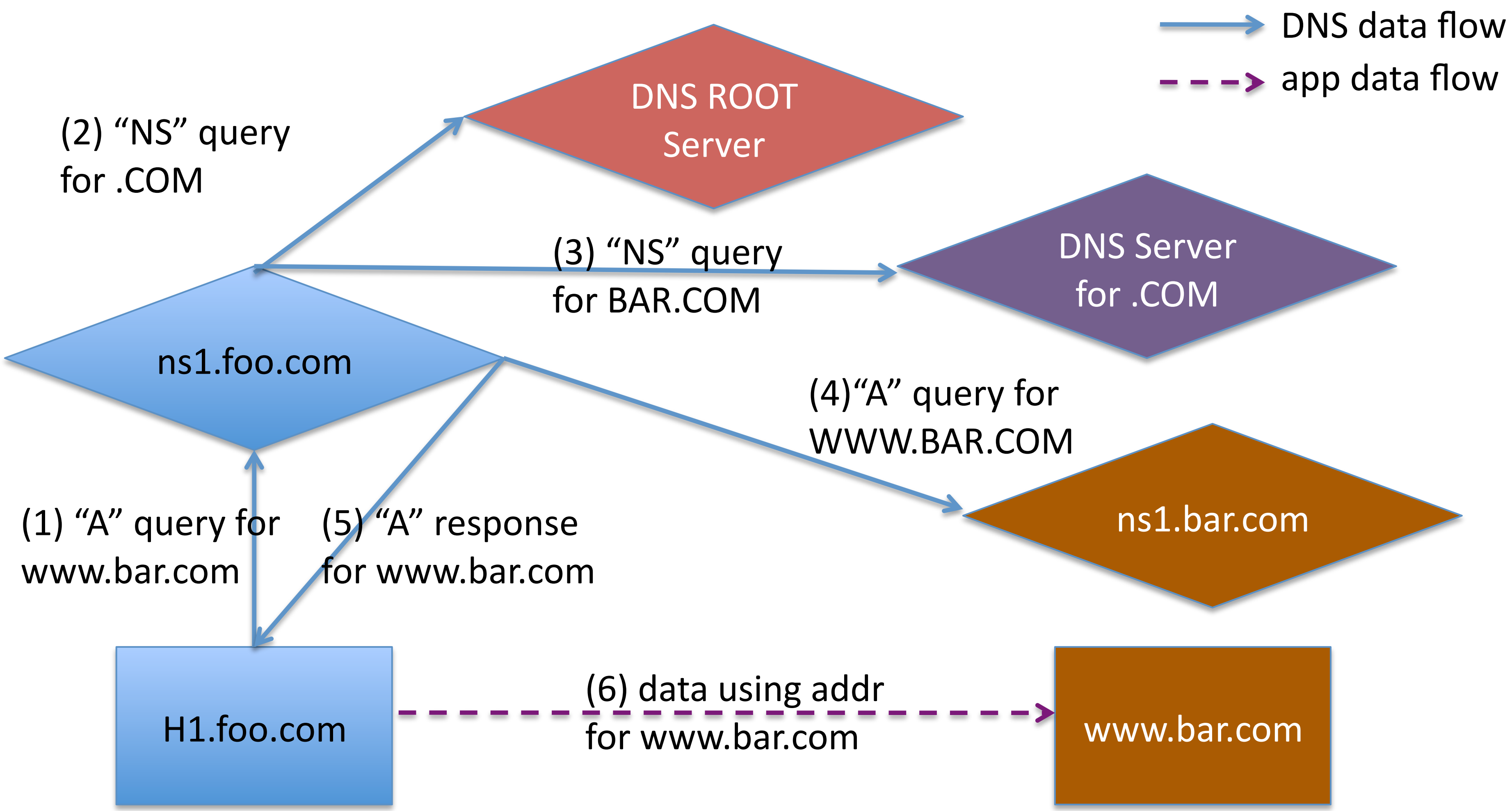
Layer	IP	ILNP
Application	FQDN or IP address	FQDN
Transport	IP address + port no.	Identifier + port no.
Network	IP address	Locator

- ILNP: cleaner semantics for naming in the IP stack:
  - Assumes consistent use of DNS names in applications
  - Uses DNS for mobility, multi-homing, traffic engineering …
  - http://ilnp.cs.st-andrews.ac.uk/
- So, DNS performance is important for ILNP
- But this talk is not about ILNP …

DNS System Architecture

- Globally distributed name space
- Globally distributed name servers each holding mappings for part of the name space
- Traditionally, read-only for end users
- Enhancements now widely available to enable write access for end users:
  - Secure DNS Dynamic Update (RFC-3007)
  - DNS Security (RFC-4033 to 4035) also useful
  - Implemented in BIND, MS Windows, MS Server

DNS Lookup Sequence



Dynamic write access to DNS

- Write access is now available for end users
- There is a temporal caching hierarchy across the spatial distribution of names:
  - Different records get cached for different periods of time, e.g. NS records and A records
  - Maximum caching time defined by a Time To Live (TTL) value held in each DNS record.
- ***Could these two features be exploited in some sensible ways?***

(Non-)Effectiveness of DNS caching

- Jung, J., Sit, E., Balakrishnan, H., and Morris, R. 2002. *DNS performance and the effectiveness of caching*. IEEE/ACM Trans. on Networking. Vol. 10, No. 5 (Oct. 2002), pp. 589-603.
- DNS caching is ineffective for edge sites:
  – trace-driven emulation (no experiments)
  – A records could have low TTL (e.g. below 1000s)
  – such low TTL would have low impact on DNS load

DNS experiments at StA [1]

- Experiments in Q1/2008
- Modify TTL values of records in operational DNS server at School of CS, St Andrews
  – 2 DNS servers: BIND 8.2.4 running on Linux
  – ~400 DNS clients: BSD, Linux, Mac, & Windows
- TTL values for successive 7-day periods during normal semester:
  – Changed DNS TTL on BIND
  – used TTL values 1800s, 60s, 30s

DNS experiments at StA [2]

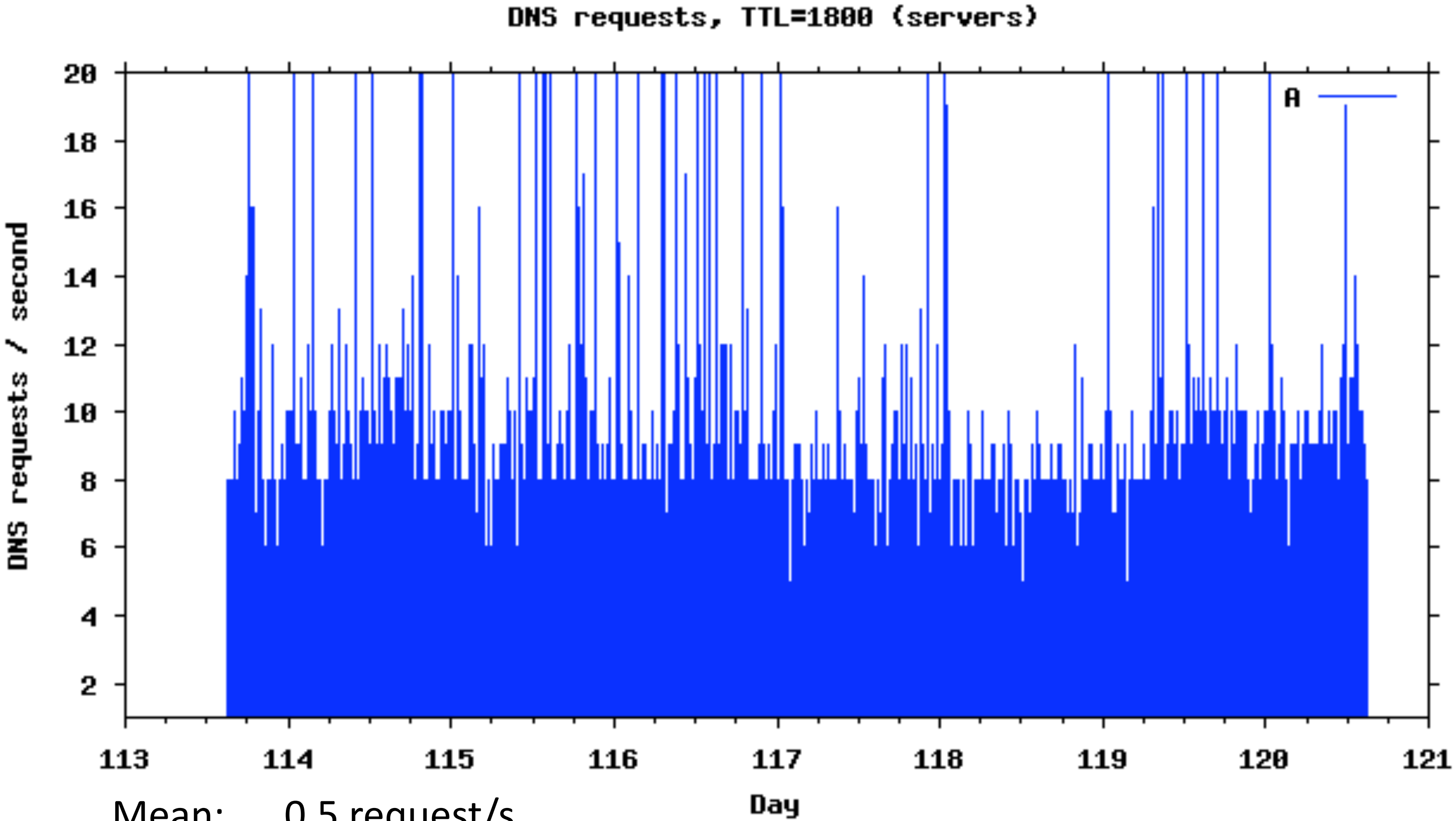
- Passive collection of packets via port mirror:
  - *tcpdump(8)* targeting *port 53*
  - Captured all DNS packets
- Results shown on following slides are for:
  - A record requests for servers only during the capture period (relevant to ILNP, and less 'noisy' data)
  - 1 second buckets
- Basic statistics:
  - on time-domain data
- Spectral analysis (post-pub verification pending!):
  - examination of request rates
- Analysis: home-brew scripts using NumPy package

Basic dataset meta-data

Data set name	TTL [s]	Duration [s][1]	Total DNS packets captured[2]	Number of A record requests for 44 servers[3]
dns1800	1800	604,740	9,841,469	303,442
dns60	60	604,739	10,420,760	609,811
dns30	30	604,800	10,979,131	911,537

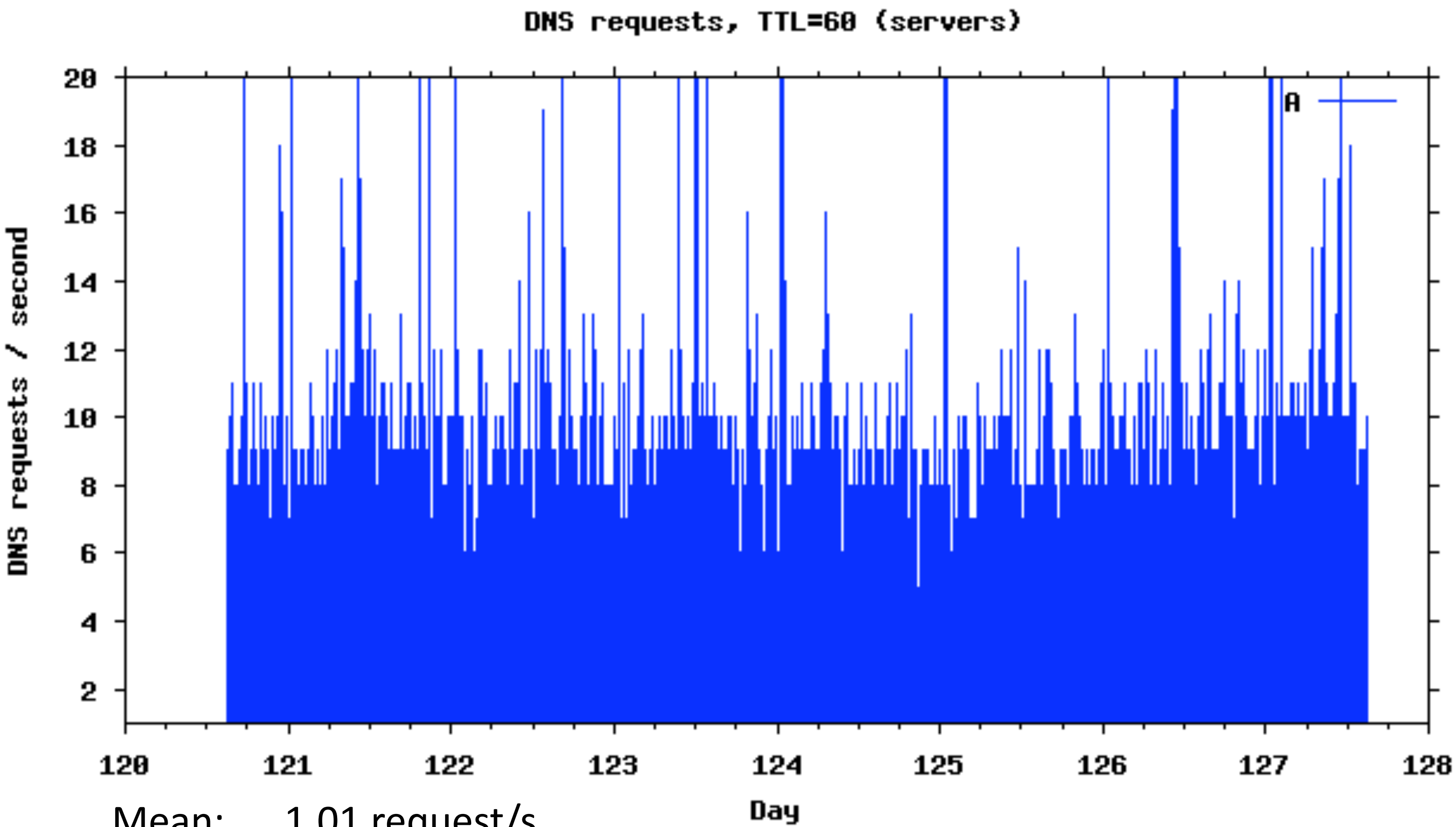
[1] from tcpdump timestamps, rounded to nearest second, 7 days = 604,800 seconds
[2] includes all request and response packets to/from port 53 (TCP and UDP), including erroneous requests etc
[3] servers that were active during the 3 weeks of data capture

dns1800: A record requests TTL=1800s



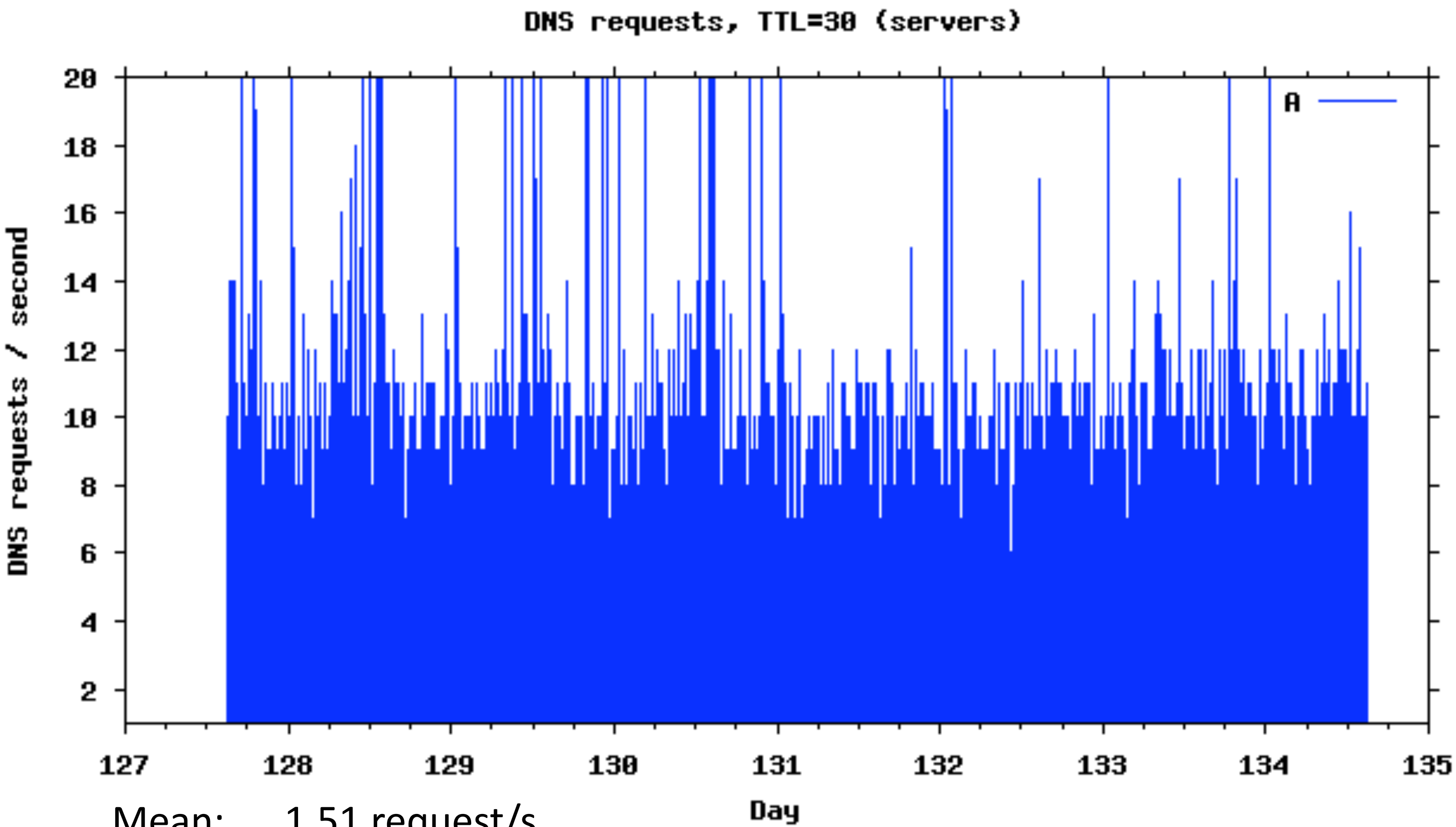
Mean: 0.5 request/s
Std Dev: 1.17 requests/s
Max: 82 requests/s

dns60: A record requests TTL=60s



Mean: 1.01 request/s
Std Dev: 1.29 requests/s
Max: 67 requests/s

dns30: A record requests TTL=30s



Mean: 1.51 request/s
Std Dev: 1.54 requests/s
Max: 116 requests/s

Summary of basic statistics

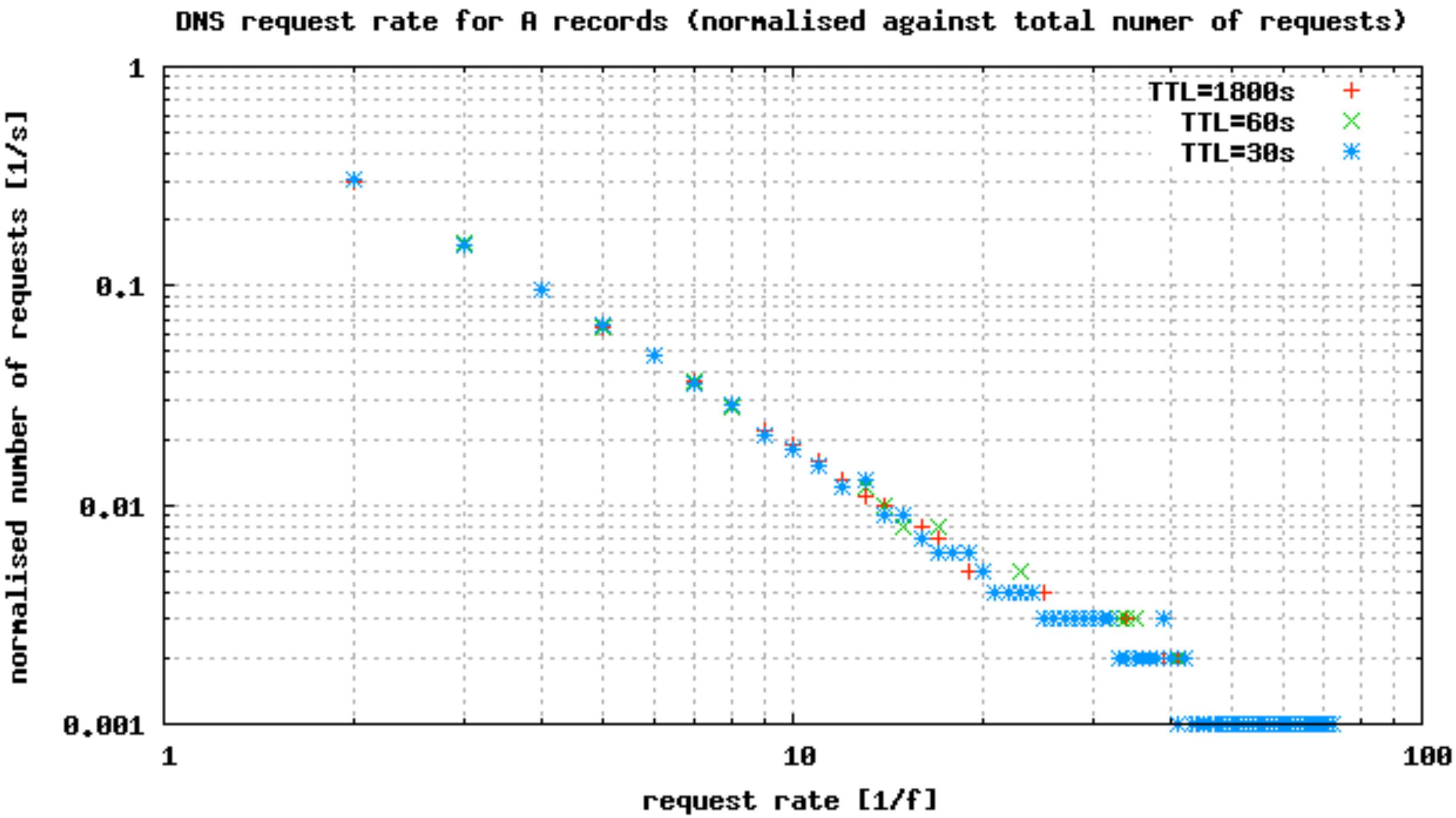
Data set name	Mean [request/s]	Std Dev [requests/s]	Maximum [requests/s]
dns1800	0.50	1.17	82
dns60	1.01	1.29	67
dns30	1.51	1.54	116

60 fold drop in TTL values
results in (only)
3 fold increase in A record requests

Basic spectral analysis (post-pub verification pending!)

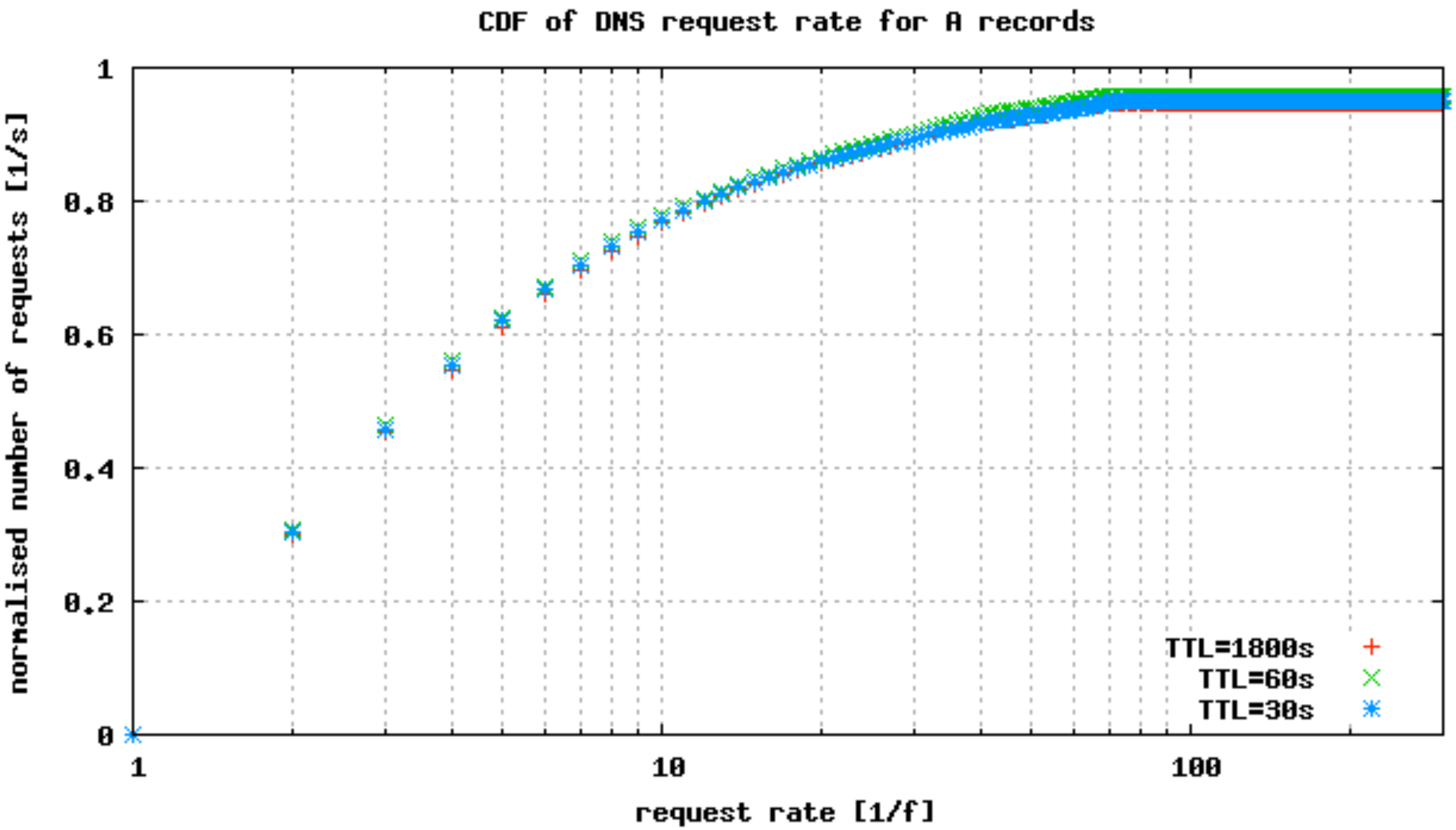
- 1s bucket, sampling at 0.5Hz in the data:
  - assumption about request rates, not verified!
- NumPy:
  - rfft() gives real part of FFT (of bucketed data)
  - fftfreq() gives frequency components
- Plot request rate using transformed FFT plot:
  - y-axis: normalise amplitude to show relative performance across data sets as requests/s (1/s)
  - x-axis: show request rates as 1/frequency (1/f)
- CDF of modified-FFT

Request rate (from FFT)



Zipf distribution (need to verify).

CDF of request rate



80% of requests < ~13s (need to verify).

Summary of basic spectral analysis

- The overall behaviour of applications in making DNS A record requests for TTL values of 1800s, 60s and 30s is much the same.
- The distribution for DNS A record request rates seem to follow a power-law distribution.
- TTL values for A records below ~13s are likely to be possible without major impact on application behaviour or DNS load.

So far, our discussion presents a technical (academic) curiosity.

The interesting question really is:
"So, what?"

What is possible if DNS TTL were zero?

- Dynamic, frequent, & authenticated DNS updates possible:
  - Simulated by Pappas, Hailes, & Giaffreda, published in LCS 2002
  - Very useful for mobility/multi-homing aspects of ILNP
- High-speed load balancing and VM mgmt for data centres
- Support for mobility and multi-homing:
  - Location updates give changes in connectivity
- Help defend against certain network attacks:
  - DNS cache poisoning for end-sites
  - DDoS: fast-cycle multi-homing (i.e. a kind of "fast-flux" DNS for defence rather than attack)
  - Others possible ...
- Potential for edge-site based multi-path and TE control:
  - multiple Locator values and DNS L record preferences

Who would set DNS TTLs so low?

- Real A record values for some servers:
  - TTL = 60 seconds: www.yahoo.com
  - TTL = 20 seconds: content servers in akamai.net
  - TTL = 0 seconds: www.cs.st-andrews.ac.uk
- Note that a site would NOT set low TTLs for:
  - Its own NS records, which identify its DNS servers.
  - The A records related to its NS records.
  - A (mobile) site can remote some or all of its authoritative DNS servers; some sites do so today.

Ongoing DNS experiments at StA

- More measurements in Q1/2009:
  - Site is now using Microsoft Active Directory for its DNS servers
  - Tuning of client-side OS and browser caches to reduce end-system caching effects on DNS data
- Q1/2009 experiments:
  - using TTL values of 1800s, 60s, 30s, 15s, 0s
  - ~150GB of data collected so far
  - analysis in progress …

Operational Considerations

- Implied semantics of TTL value:
  - **gotcha**: some systems assume that, if network outage time > TTL, then service is down
- PAM2003, PAM2004, NETTS2004 papers by Wessels *et al.*:
  - http://dns.measurement-factory.com/writings/
- In fact, the main site has some very interesting reading, including:
  - http://dns.measurement-factory.com/surveys/200810.html

Summary and Conclusion

- Summary:
  - Very low TTL values for edge-site DNS records possible
  - DNS load with very low DNS TTLs seems manageable
- Conclusion:
  - Both frequent DNS accesses and frequent Dynamic DNS Updates seem practical to deploy
- What next?
  - More experiments with naming usage (and ILNP)
  - Try experiments with Secure Dynamic DNS updates
- Thanks to:
  - Martin Bateman for tcpdump/DNS data collection
  - Systems Group at cs.st-andrews.ac.uk for DNS TTL changes