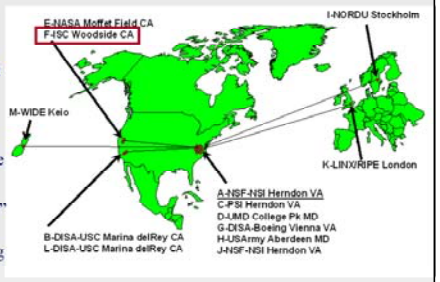
DNS: Root Name Servers

- contacted by local name server that can't resolve name
- root name server:
  - »provides pointers to authoritative servers at lower level of name hierarchy
- 13 "conventional" root name servers worldwide

- 20+ copies of "F-server" worldwide reached by specialized BGP routing

Root Server Distribution, 2003



Root Server Distribution - 2006

Figure 1: Root Server Locations and Areas of Redundant Connectivity

Gibbard, S., "Geographic Implications of DNS Infrastructure Distribution", *Internet Protocol Journal*,Vol. 10, No. 1, March 2007, pp. 12-24.

Generic TLD Servers Distribution -2003

.com & .net code Zone Server Locations

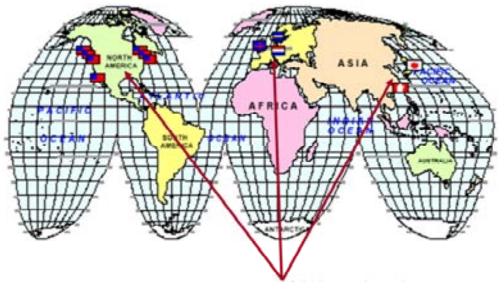
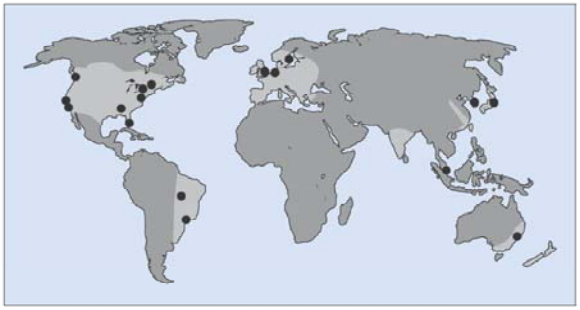


Figure 1 Global gTLD Locations

13 independent sites

Generic TLD Servers Distribution -2006 (.com, .net)

Figure 2: Server Locations for .com and .net and Areas of Redundant Connectivity



Gibbard, S., "Geographic Implications of DNS Infrastructure Distribution", *Internet Protocol Journal*,Vol. 10, No. 1, March 2007, pp. 12-24.

Generic TLD Servers Distribution -2006 (.org, .info, .mobi)

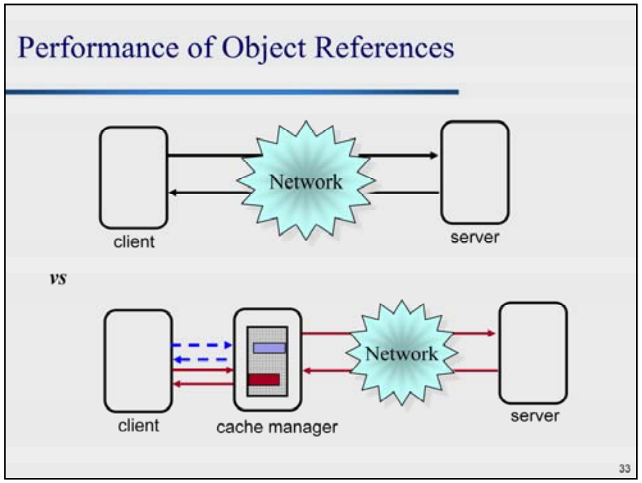
Figure 3: Server Locations for .org, .info, and .mobi and Areas of Redundant Connectivity

Gibbard, S., “Geographic Implications of DNS Infrastructure Distribution”, *Internet Protocol Journal*,Vol. 10, No. 1, March 2007, pp. 12-24.

Summary of all TLD server locations

gTLD	Locations by Country or U.S. State
`.aero`	Switzerland, Germany, India, Hong Kong, United Kingdom, and the following states in the United States: California, Illinois, and Virginia
`.biz`	Australia, Hong Kong, Netherlands, New Zealand, Singapore, United Kingdom, and the following states in the United States: California, Florida, Georgia, New York, Virginia, and Washington
`.com`	Australia, Brazil, Canada, Japan, South Korea, Netherlands, Sweden, Singapore, United Kingdom, and the following states in the United States: California, Florida, Georgia, Virginia, and Washington
`.coop`	United Kingdom and the following states in the United States: California, Illinois, and Massachusetts
`.edu`	Netherlands, Singapore, and the following states in the United States: California, Florida, Georgia, and Virginia
`.gov`	Canada, Germany, and the following states in the United States: California, Florida, New Jersey, Pennsylvania, and Texas
`.info`	India, Hong Kong, South Africa, United Kingdom, and the following states in the United States: California, Illinois, and Virginia
`.int`	Netherlands, United Kingdom, and California in the United States
`.jobs`	Netherlands, Singapore, and the following states in the United States: California, Florida, Georgia, and Virginia
`.mil`	The following states in the United States: California, Maryland, Virginia, and other unknown locations
`.mobi`	India, Hong Kong, South Africa, United Kingdom, and the following states in the United States: California, Illinois, and Virginia
`.museum`	Sweden and California in the United States
`.name`	Singapore, United Kingdom, and the following states in the United States: California, Florida, Georgia, Virginia, and Washington
`.net`	Australia, Brazil, Canada, Japan, South Korea, Netherlands, Sweden, Singapore, United Kingdom, and the following states in the United States: California, Florida, Georgia, Virginia, and Washington
`.org`	India, Hong Kong, South Africa, United Kingdom, and the following states in the United States: California, Illinois, and Virginia
`.pro`	Canada and the following states in the United States: Illinois and Texas
`.travel`	Australia, Hong Kong, Netherlands, New Zealand, Singapore, United Kingdom, and the following states in the United States: California, Florida, Georgia, New York, Virginia, and Washington

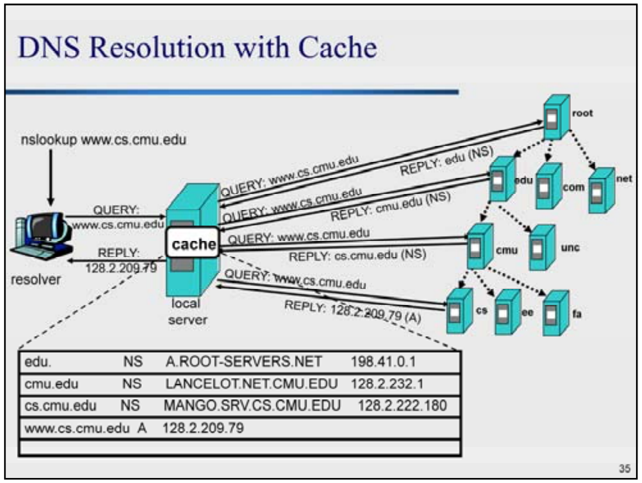
Gibbard, S., “Geographic Implications of DNS Infrastructure Distribution”, *Internet Protocol Journal*,Vol. 10, No. 1, March 2007, pp. 12-24.



Performance of Object References

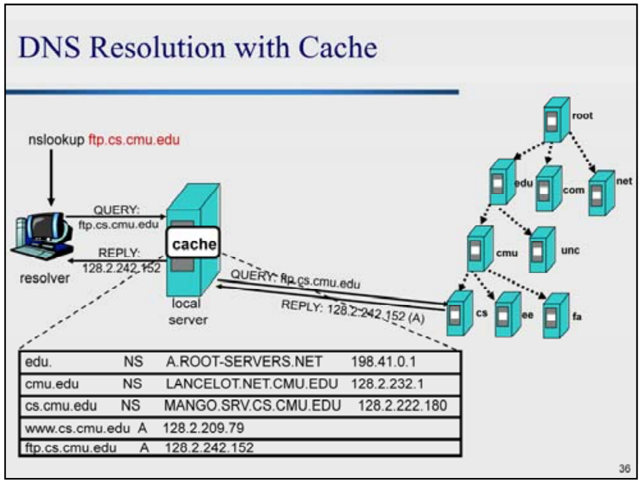
Cache Design Issues

- Size
  - » influences "hit ratio" (though DNS caches are typically not size-limited)
  - » $T_{avg.}$ = hit_ratio * $T_{avg.\text{-}cache}$ + (1 - hit_ratio) * $T_{avg.\text{-}remote}$
- Replacement
  - » free space for new data when full
  - » Usually not critical for DNS caches, since most are not size-limited
- (in)Validation
  - » does the cache hold "current" information?
- Location
  - » memory vs disk (speed vs size)



DNS Resolution with Cache

edu.	NS	A.ROOT-SERVERS.NET	198.41.0.1
cmu.edu	NS	LANCELOT.NET.CMU.EDU	128.2.232.1
cs.cmu.edu	NS	MANGO.SRV.CS.CMU.EDU	128.2.222.180
www.cs.cmu.edu	A	128.2.209.79	



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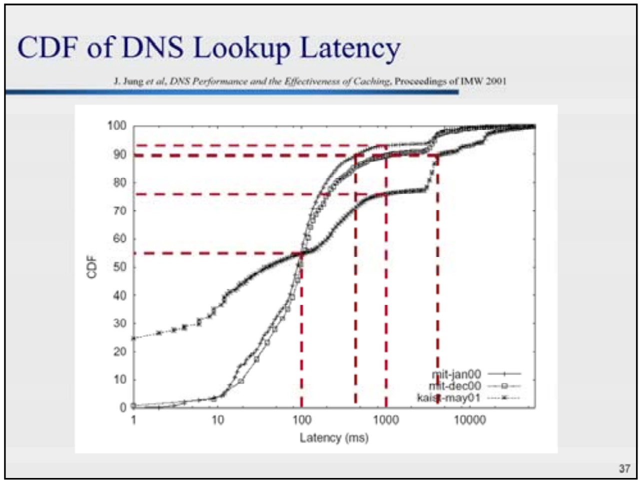
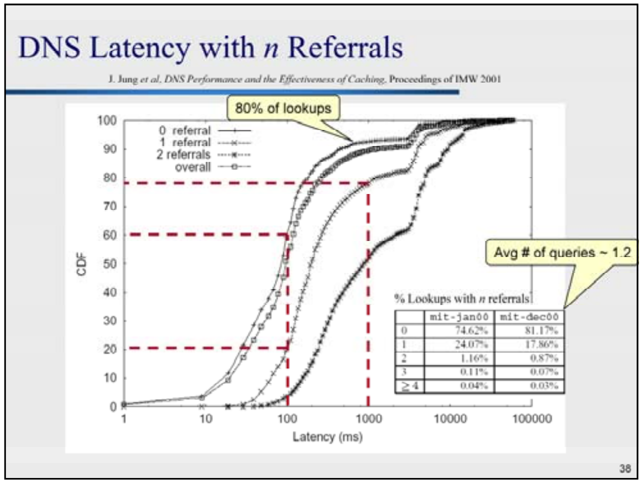
www.cs.cmu.edu	A	128.2.209.79	
ftp.cs.cmu.edu	A	128.2.242.152	



CDF of DNS Lookup Latency

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001



DNS Latency with *n* Referrals

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001

80% of lookups

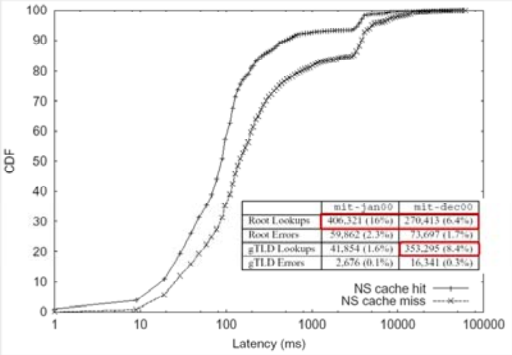
Avg # of queries ~ 1.2

% Lookups with *n* referrals

	mit-jan00	mit-dec00
0	74.62%	81.17%
1	24.07%	17.86%
2	1.16%	0.87%
3	0.11%	0.07%
≥ 4	0.04%	0.03%

DNS Latency with Query to Root

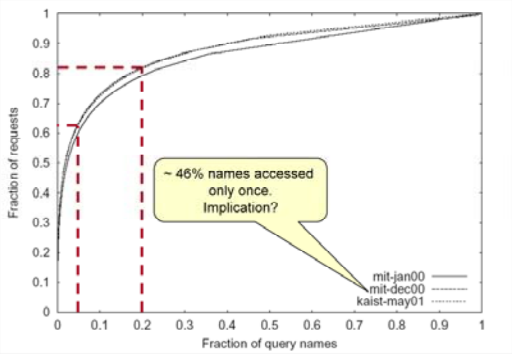
J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001



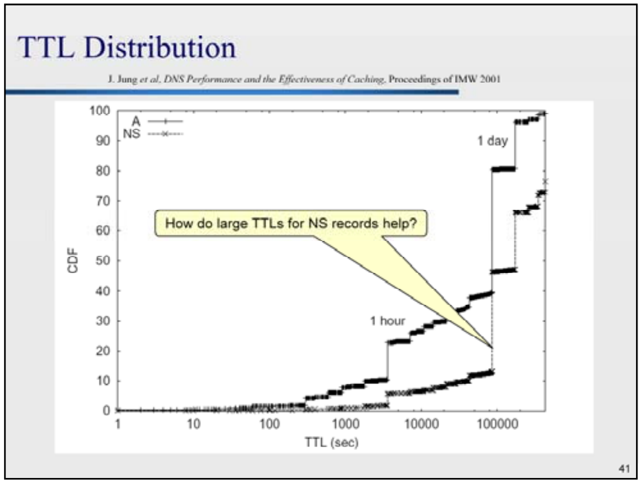
	mit-jan00	mit-dec00
Root Lookups	406,321 (16%)	270,413 (6.4%)
Root Errors	59,862 (2.3%)	73,697 (1.7%)
gTLD Lookups	41,854 (1.6%)	353,295 (8.4%)
gTLD Errors	2,676 (0.1%)	16,341 (0.3%)

Most Popular Names *vs* % Requests

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001



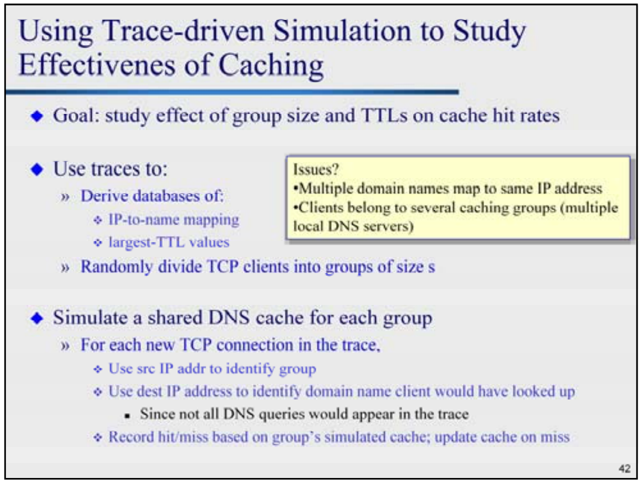
~ 46% names accessed only once. Implication?



TTL Distribution

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001

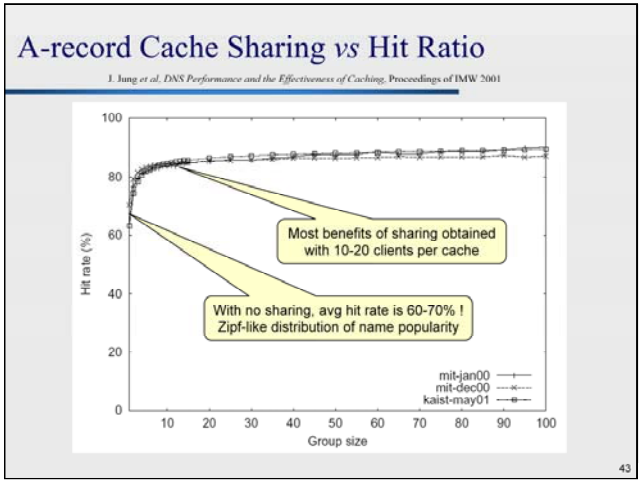
How do large TTLs for NS records help?



Using Trace-driven Simulation to Study Effectivenes of Caching

- Goal: study effect of group size and TTLs on cache hit rates
- Use traces to:
  - Derive databases of:
    - IP-to-name mapping
    - largest-TTL values
  - Randomly divide TCP clients into groups of size s
- Simulate a shared DNS cache for each group
  - For each new TCP connection in the trace,
    - Use src IP addr to identify group
    - Use dest IP address to identify domain name client would have looked up
      - Since not all DNS queries would appear in the trace
    - Record hit/miss based on group's simulated cache; update cache on miss

Issues?
•Multiple domain names map to same IP address
•Clients belong to several caching groups (multiple local DNS servers)



A-record Cache Sharing *vs* Hit Ratio

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001

Most benefits of sharing obtained with 10-20 clients per cache

With no sharing, avg hit rate is 60-70% ! Zipf-like distribution of name popularity

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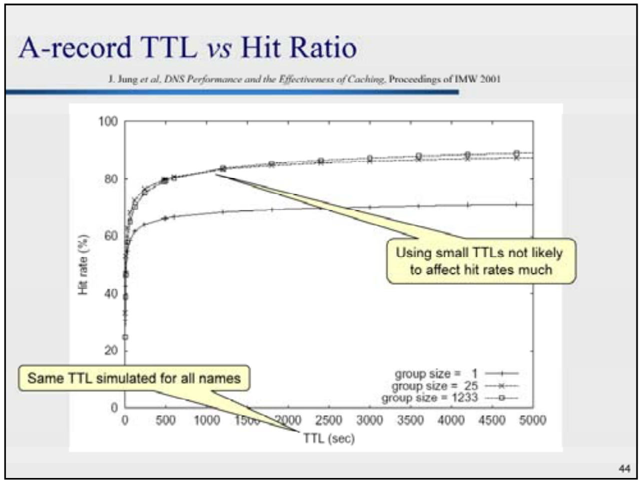

A-record TTL *vs* Hit Ratio

J. Jung *et al*, *DNS Performance and the Effectiveness of Caching*, Proceedings of IMW 2001

Using small TTLs not likely to affect hit rates much

Same TTL simulated for all names

Using Trace-driven Simulation to Study Effectivenes of Caching

- Per-client or per-application caching of A records can almost entirely handle the job of reducing client-latency
- Not a good idea to reduce TTL values on NS-records (or for A-records for name servers)
  - » Would increase the load on root and gTLD servers by a factor of 5 !
  - » Local proxy-based caching helps significantly reduce load on root servers

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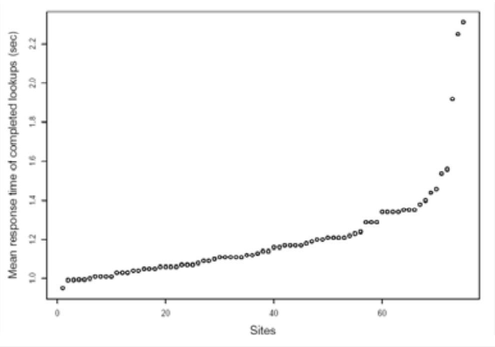
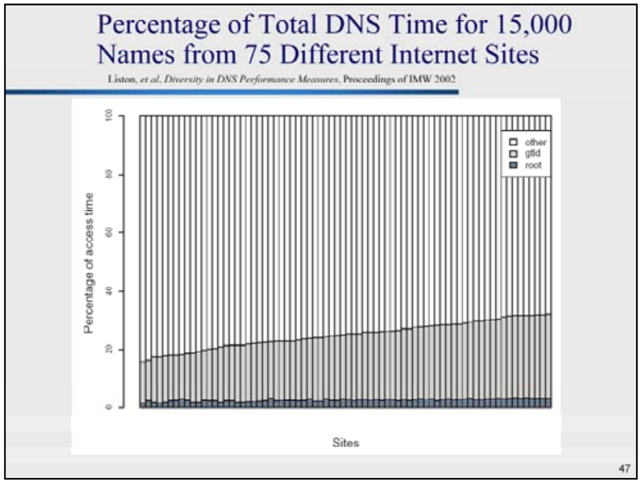
Mean DNS Time for 15,000 Names from 75 Different Internet Sites

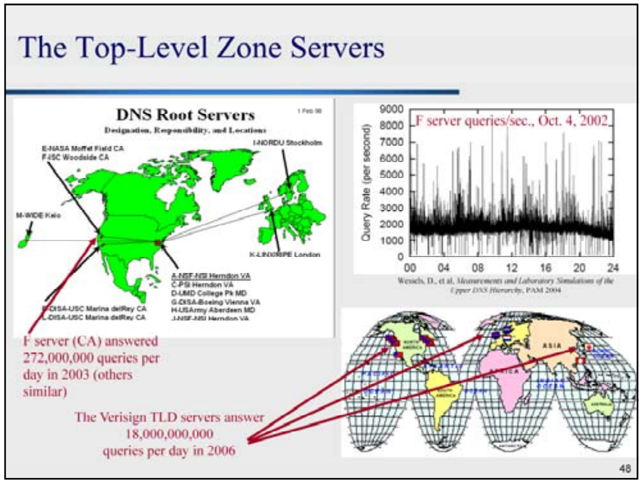
Liston, *et al*, *Diversity in DNS Performance Measures*, Proceedings of IMW 2002





Percentage of Total DNS Time for 15,000 Names from 75 Different Internet Sites

Liston, *et al, Diversity in DNS Performance Measures*, Proceedings of IMW 2002

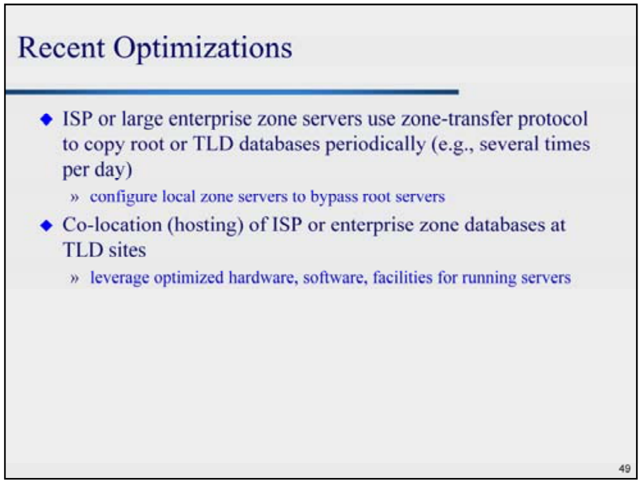


The Top-Level Zone Servers

F server (CA) answered 272,000,000 queries per day in 2003 (others similar)

Wessels, D., et al, *Measurements and Laboratory Simulations of the Upper DNS Hierarchy*, PAM 2004

The Verisign TLD servers answer 18,000,000,000 queries per day in 2006



Recent Optimizations

- ISP or large enterprise zone servers use zone-transfer protocol to copy root or TLD databases periodically (e.g., several times per day)
  - » configure local zone servers to bypass root servers
- Co-location (hosting) of ISP or enterprise zone databases at TLD sites
  - » leverage optimized hardware, software, facilities for running servers