# End-user mapping: Next-Generation Request Routing for Content Delivery

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## Introduction

Assign client to “proximal” server through DNS: translate Domain Name to server’s IP

mapping: map client to server

(proximal & balanced)

reduce delay & balance load

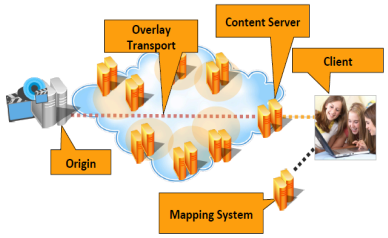



Figure 1: A Content Delivery Network

## NS-based mapping vs end-user mapping

NS-based mapping

$$\mathrm{MAP_t} : \Sigma_{\mathrm{Internet}} \times \Sigma_{\mathrm{Akam}} \times \mathrm{Domain} \times \mathrm{LDNS} \rightarrow \mathrm{IPs}. \quad (1)$$

end-user mapping

$$\mathrm{EUMAP_t} : \Sigma_{\mathrm{Internet}} \times \Sigma_{\mathrm{Akam}} \times \mathrm{Domain} \times \mathrm{Client} \rightarrow \mathrm{IPs}. \quad (2)$$

## Mapping system architecture

- network measurement

1) AS-level information (topology)
2) Geographical information
3) Name Server information (LDNS)
4) Network-level information (path, latency, loss, throughput)
5) Liveness & load (edge server)

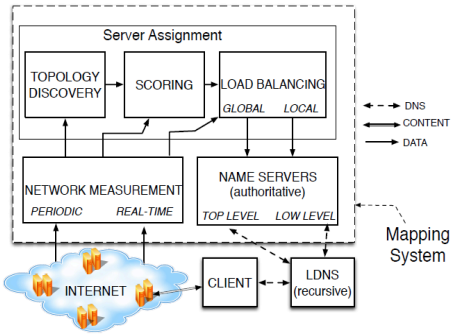



Figure 3: The architecture of the mapping system

# Mapping system architecture

- server assignment

topology map: evaluate the likely performance if client is signed to each server cluster

scoring: different fuctions of bandwidth, latency, packet loss etc. for different traffic class e.g. web, video, app…

load balancing: global: assign a server cluster; local: assign one server within the cluster.

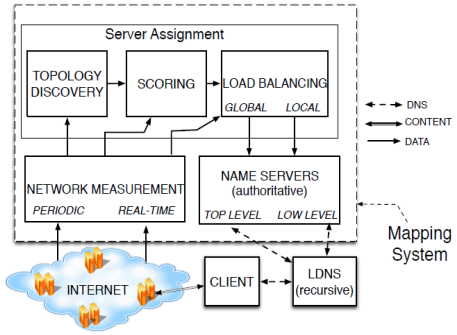



Figure 3: The architecture of the mapping system

# Mapping system architecture

- name server

content provider CNAME their domain to a akamai domain

www.whitehouse.gov

CNAME TO

e2561.b.akamaiedge.net
(delegate to cluster close to client's LDNS, chosen by global load balancer)

RESOLVE TO

"A record" for two or more server IPs
(chosen by local load balancer)

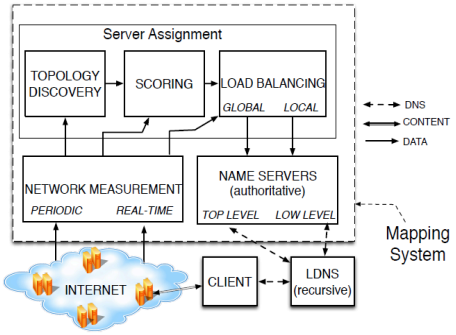



Figure 3: The architecture of the mapping system

# End-user mapping

Major difference

In NS-based mapping, authoritative NS only knows IP (geo location) of LDNS

In end-user mapping, authoritative NS also knows IP (geo location) of client

*enabler: EDNS0 client-subnet extension*

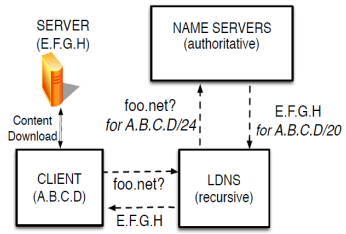



Figure 4: Example of interaction between the client, LDNS, and Akamai's name servers with the EDNS0 extension.

# Collecting Client-LDNS pairs

NetSession: Akamai's download manager

1) NetSession client maintains a persistent connection with NetSession control panel to learn external client IP (even behind NAT)

2) NetSession client perform "dig" on whoami.akamai.net, and sent LDNS association to Akamai cloud storage

3.76 million /24 client IP blocks, covers 84.6% of total global client demand served by akamai

# Client-LDNS distance

akaimai's Edgescape geo-location database

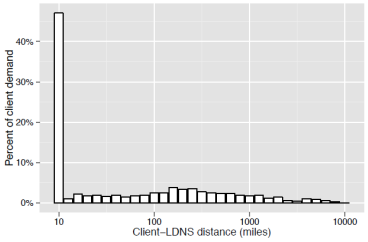



Figure 5: Histogram of client-LDNS distance for clients across the global Internet.

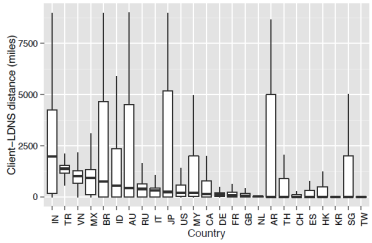



Figure 6: Client-LDNS distances by country.

# Public resolver

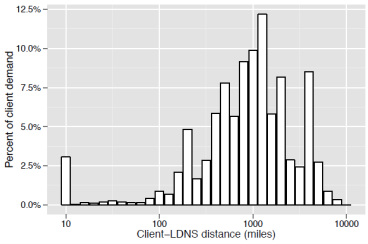



Figure 7: Histogram of the client-LDNS distance for clients who use public resolvers.

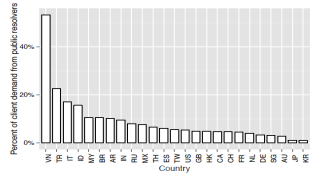



Figure 9: Percent of client demand originating from public resolvers, by country.

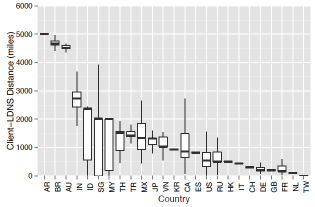



Figure 8: Client-LDNS distance for clients who use public resolvers.

# Breakdown by ASes

Size is percentage of client demand from that AS served by akamai

2^-1 means 0.5%

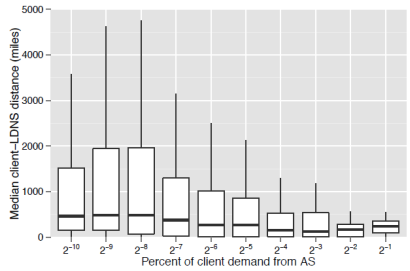



Figure 10: Client-LDNS distance as a function of AS size.

- small ISPs use public resolver, because don't have the resourses to run their own system
- enterprices with geographically diverse branch offices use a centralized name server deployed in one of the office

# Distance between clients that use the same LDNS

client cluster: set of clients use same LDNS (basic unit in NS-based mapping)

radius of cluster: mean distance to the centroid

if radius is small, a NS-based mapping can still do a good job, even if client-LDNS distance is large (not for large radius)

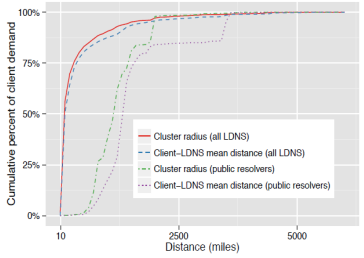
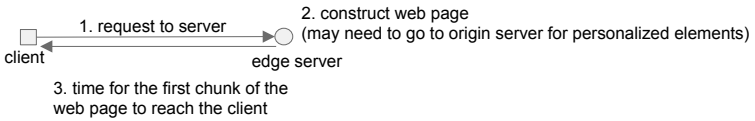



Figure 11: CDFs of mean client-LDNS distance and cluster radius for all LDNSes and for the subset that are public resolvers.

- client-LDNS distance > radius of cluster: LDNS is usually not deployed at a "central" location within the cluster.
- For public resolver, both client-LDNS distance and radius of cluster are large.

# Performance evaluation

1) Are distances between clients and servers decreased?
    a) Geographic distance
2) Are the RTTs between clients and servers decreased?
    a) State of network path (e.g., propogation and congestion)
3) Is time to first byte (TTFB) decreased?
    a) TTFB: duration btw HTTP request and first type of web page received
    b) Three components
4) Download time




# Why download performance matter?

Walmart as an example:
100 ms decrease → 1% increase in revenue
1 s decrease → 2 % increase in conversion rates

250 ms faster than competing sites → a significant business advanatege

short mapping distance → stable and reliable paths

# Performance evaluation

To study performance impact, countries are classified into two groups:

1) High expectation group
    a) End-user mapping expected to have a greater impact
    b) Clients residing in countries where median distance to a public resolver > 1000 miles
2) Low expectation group
    a) End-user mapping expected to have a lower impact
    b) Clients residing in countries where median distance to a public resolver < 1000 miles

# Mapping distance

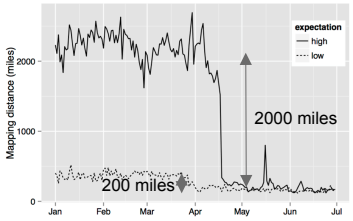



Figure 13: Daily mean of mapping distance.

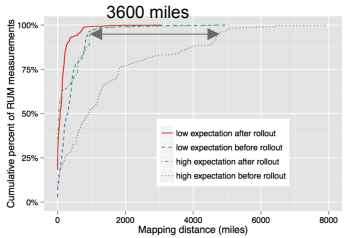



Figure 14: CDFs of mapping distance.

Example: Brazil uses DNS in North America

# RTT

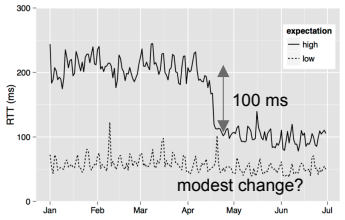



Figure 15: Daily Mean of Round Trip Time (RTT).

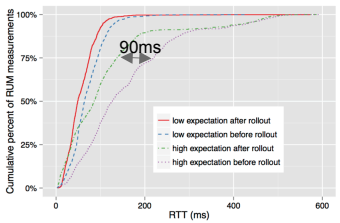



Figure 16: CDFs of Round Trip Time (RTT).

# Time-to-first-byte

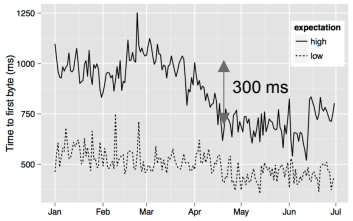



Figure 17: Daily Mean of Time to First Byte (TTFB).

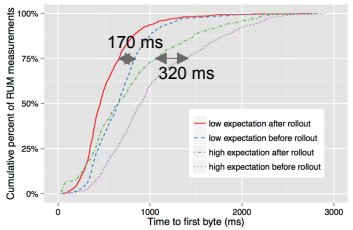



Figure 18: CDFs of Time to First Byte (TTFB).

# Content download time

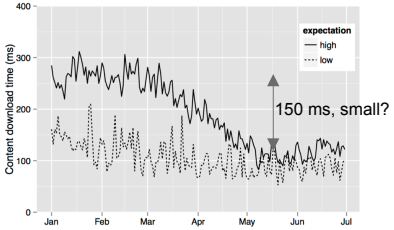



Figure 19: Daily mean of content download time.

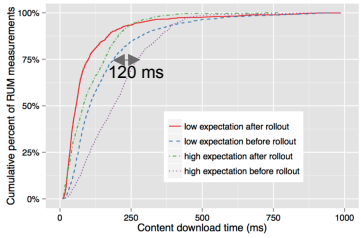



Figure 20: CDFs of content download time.

# Benefits of EDNS0 adoption

Great improvements for clients using public DNS

What about clients using LDNS?

1. 6.2% of clients use LDNS > 1000 miles away
    a. Through extrapolation, 50% reduction in RTT and download time
2. 5.3% of clients using LDNS greater than 500 & less than 1000 miles
    a. Through extrapolation, 24% reduction in RTT and download time

Total percentage of clients: 8% public DNS + 11.5% local DNS

# Scaling challenges

Using /24 IP blocks as mapping units?

Mapping units: the set of clients sharing the same server assignment decision

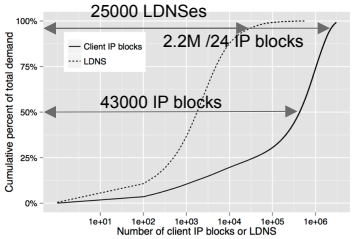
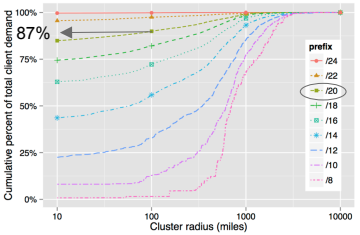


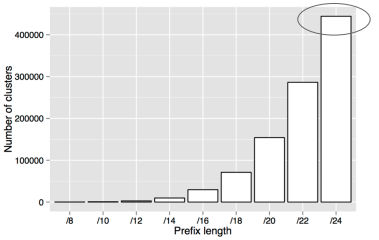

Figure 21: Number of /24 client IP blocks or LDNSes that produce a given percent of total global demand.

# Scaling challenge




(a) Histogram of the cluster radius for /x client IP blocks.

50% of client demand is used




(b) Number of /x client IP blocks with non-zero demand.

# Greater query rates

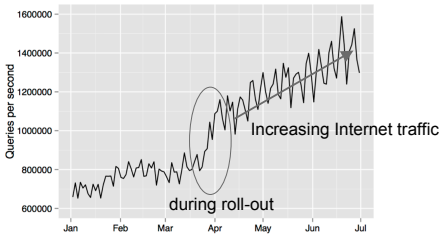
In NS-based mapping:

- clients using the same LDNS are directed to the same server
- each domain name ⇔ each resolution

In end-user mapping:

- clients using the same LDNS may be directed to different servers
- each domain name + each IP block ⇔ each resolution
- In other words, each domain name ⇔ multiple resolutions

# Greater DNS query rates




# of queries from public resolvers increase 8 times

Figure 23: DNS queries received by Akamai's name servers from LDNSes showed a significant increase during the end-user mapping rollout.

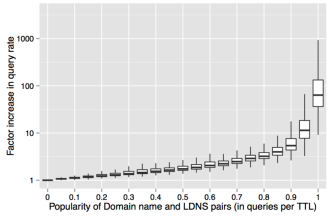



Figure 24: More popular domain name and LDNS pairs show a greater increase in query rate after the roll-out.

Bucket each domain name and LDNS with # of queries per TTL prior to roll-out

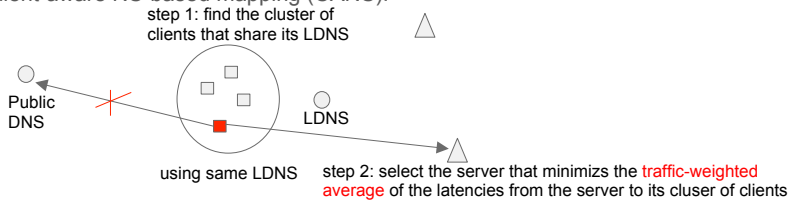
## Server deployments

What role do deployments play in performance benefits of end-user mapping?

Should a CDN with a small number of delployment locations adopt EU mapping?

How much can NS-based mapping being improved by making it client-aware?

Client-aware NS-based mapping (CANS):




## Server deployment

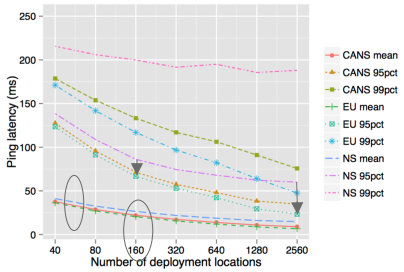



Figure 25: Latencies achieved by EU, CANS, and NS mapping as a function of CDN deployment locations.

1. more servers, less latency
2. identical performance (most clients are close to their LDNSes)
3. for worst-performance clients, **larger deploy, larger latency reduction** by switching from NS to EU
4. After 160 deployments, improvement to NS-based mapping is diminishing (it doesn't work well for clients who are away from LDNSes)

## Discussion

Any improvements for clients using the closest (geographically) server?

- Clients using the closest server =? best
- Geographic distance =? propogation delay
- Queueing delay?

If /20 IP blocks are the best mapping units?

- Variable-length IP blocks considering both scalability and accuracy?

How to measure the performance between servers and large-scale mapping units?

Is a query rate a problem if end-user mapping is widely used?